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# SURGE FACILITY FOR WET AND DRY WEATHER FLOW CONTROL

Harold L. Welborn

City of Rohnert Park, California

Prepared for:

National Environmental Research Center
Y-T-O and Associates

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The surge facility tested in this EPA Demonstration Project provided peak flow equalization and some degree of treatment to all storm flows and rate control of all wet and dry weather wastewater flows. The Rohnert facility was designed to test a method whereby solids could be prevented from accumulating on the bottom of an inexpensive earthen, lined basin without the use of conventional mechanical sludge collection equipment. The principal features of the surge facility were a 2,841 cubic meter (0.75 million gallon) Sedimentation-Equalization Basin, variable underflow pumps, a surface aerator and Pool Sweeps. The Pool Sweeps were used to continuously "sweep" the bottom and sides of the earthen, lined basin to move and temporarily resuspend the settled sewage solids and, thereby, maintain the flow of solids in the absence of mechanical collection mechanism, steep bottom slopes, or a completely mixed basin. Under the storm flow conditions, the surge facility removed approximately 45 percent of the influent Suspended Solids and 90 percent of influent Settleable Solids prior to overflow to a storage pond. Although a significant portion of the solids flow through the surge basin could be attributed to the operation of the Pool Sweeps, their overall performance could not justify their use in other similar facilities.

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# SURGE FACILITY FOR WET AND DRY WEATHER FLOW CONTROL

By

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For

City of Rohnert Park
Rohnert Park, California 94928

Demonstration Project No. S800769
Program Element 1BB034

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## FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment -- air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

This particular effort demonstrated how one facility can be optimally utilized to provide flow equalization for wet and dry-weather wastewater flows as well as some degree of treatment to storm flows.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

## ABSTRACT

This report represents the culmination of a three-year project which encompassed the design, construction, operation, testing and evaluation of a surge facility designed to provide flow equalization and some degree of treatment to all storm flows and to provide rate control of wet weather and dry weather wastewater flows to interceptor sewers.

The Rohnert Park Demonstration Project was designed to test a method whereby solids could be prevented from accumulating on the bottom of an inexpensive earthen, lined basin without the use of conventional mechanical sludge collection equipment.

The overall costs for the demonstration facilities included: $32,400 for design; $370,000 for construction; and $14,000 for construction inspection. The major mechanical equipment costs are estimated at approximately $80,000.

An economic evaluation showed that it was advantageous to use a surge facility at Rohnert Park as part of a regional plan to transport its wastewater to the Regional Plant rather than pump the entire wet weather peak flows.

The principal features of the surge facility were a 2,841 cubic meter (0.75 million gallon) Sedimentation-Equalization Basin, variable underflow pumps, a surface aerator and Pool Sweeps. The Pool Sweeps were used to continuously "sweep" the bottom and sides of the earthen, lined basin to move and temporarily resuspend the settled sewage solids and thereby maintain the flow of solids in the absence of mechanical collection mechanism, steep bottom slopes or a completely mixed basin.

The full size facility was tested under actual field conditions with influent flows varying from a low of 25 to a high of 243 liters per second (400 to 3,850 gallons per minute).

The ability of the surge facility to provide adequate hydraulic control to eliminate diurnal flow variations was documented early in the Demonstration Period.

Under storm flow conditions, at which time the Sedimentation-Equalization Basin was operating at over 90 percent of its design capacity of 6.0 mgd, the surge facility was able to remove approximately 45 percent of the influent Suspended Solids and over 90 percent of the influent Settleable Solids. BOD removal under storm flow conditions was not significant.

Although a significant portion of the solids flow through the surge basin could be attributed to the operation of the Pool Sweeps, their overall performance could not justify their use in other similar facilities.

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The cooperation of the City of Santa Rosa and, in particular, Mr. Frank Poulsen, the Superintendent of Utilities, and Mr. Larry Pringle, the Plant Supervisor at the Laguna Wastewater Treatment Plant, is acknowledged with sincere thanks.

Special thanks are extended to Dr. William D. Bishop, EPA Project Officer, whose guidance throughout the project was invaluable.

# SECTION I

# CONCLUSIONS

Design and operation of surge facilities is dependent on control of hydraulics and solids flow.

By metering the influent and underflow and continuously monitoring the water surface, it was relatively easy to produce a uniform underflow rate during normal dry weather flow periods while maintaining the variation in water surface within desired limits.

The quality of overflow to the storage pond is not nearly as dependent on hydraulic loading as it is with a conventional sedimentation basin (clarifier). With normal clarifiers, the removal of BOD is directly related to the hydraulic detention time, that is, the lower the detention time the lower the percent removal. BOD removals through the Sedimentation-Equalization Basin, however, did not follow the same direct relationship. For example, at a relatively long detention time of 13.9 hours, the BOD concentration in the overflow was 12 percent higher than the influent BOD concentration. In another test, when the hydraulic detention time was 8.8 hours, there was a 79 percent removal of BOD, overflow to influent, and during a storm flow period when the hydraulic detention time was only 3.6 hours, there was no removal of BOD. The unpredictable nature of the BOD concentration through the Sedimentation-Equalization Basin appears to be the result of the production of soluble BOD from the anaerobic decomposition of settled sewage solids on the bottom of the basin. Suspended Solids and Settleable Solids removals varied from about 55 to 45 percent and about 98 to 90 percent, respectively, as the hydraulic detention time varied from 13.9 to 3.6 hours.

The basin configuration, including size, shape and flow pattern, the underflow pumping, the aerator, the Pool Sweeps and the hydraulic loading were all found to have an effect on the solids movement through the Sedimentation-Equalization Basin.

The Pool Sweep units did have an observable beneficial effect on the movement of solids through the Sedimentation-Equalization Basin but their performance, as used and modified in this Demonstration Project, did not warrant their selection as a primary sludge mover in a similar surge facility.

Operating experience with the demonstration surge facility indicated that solids which had accumulated on the bottom of the basin could be removed easily by simply drawing down the basin with the underflow pumps. After most of the

liquid wastewater was removed from the basin, the remaining sludge blanket "flowed" toward the center sump where it could be pumped out.

The "tethering" effect of the Pool Sweeps being restrained by the supply hose had a noticeable adverse effect on the mobility of the units and probably had a similar adverse effect on its overall performance.

It appears that surge facilities in the Rohnert Park and Santa Rosa area are justified on the basis of dry and wet weather flow equalization even if wet weather flows are reduced substantially by collection system rehabilitation.

## SECTION II

## RECOMMENDATIONS

More study is warranted on the solids flow-through mechanisms which exist in this type of facility.

Future surge facilities of the type used for this project should be designed with multiple basins to add more flexibility for handling the wide range of flows.

Alternative methods of removing settled solids from the bottom of the Sedimentation-Equalization Basin should be investigated. Most likely solutions include periodic lowering of the basin contents and periodic complete mixing of the basin contents.

## SECTION III

## INTRODUCTION

The City of Rohnert Park is located in the south-central portion of Sonoma County, California, approximately 60 miles north of San Francisco. The drainage area surrounding Rohnert Park is tributary to the Russian River. The city is a relatively new addition to the Santa Rosa Plain, started in 1957 and incorporated in 1962. It is primarily a residential community that is presently supported by industry outside the city, and by local industry and commerce generated from the nearby California State College in Sonoma. The Santa Rosa Plains area is shown in Figure 1.

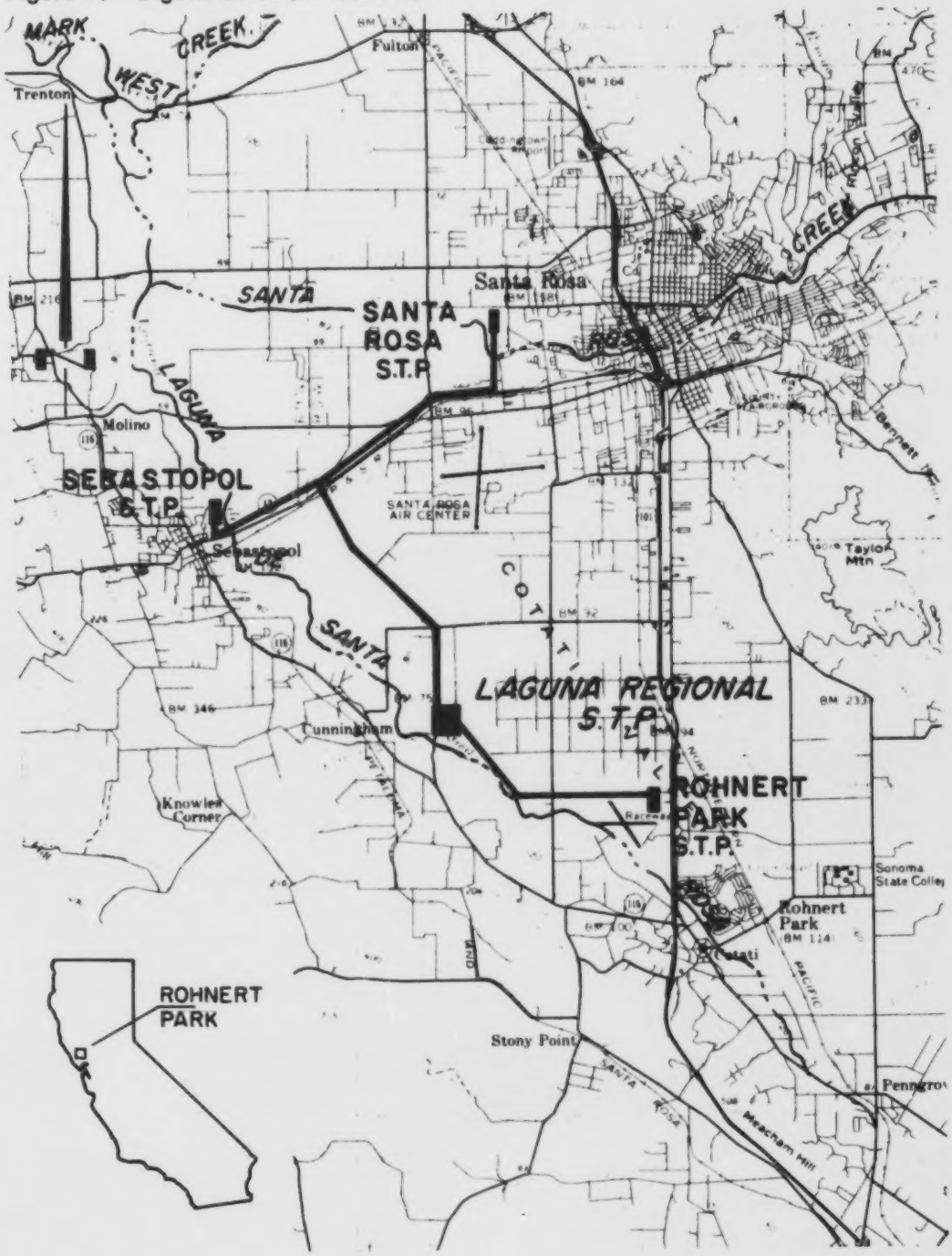
The climate of the Rohnert Park area is characterized by warm, dry summers and mild, wet winters. The mean daily maximum temperature in the summer is 80°F and the mean daily minimum temperature in the winter is 40°F. Average annual rainfall is 30 inches and average annual evaporation is 60 inches.

The original Rohnert Park Wastewater Treatment Plant was constructed in 1957. It was a primary treatment plant designed for an average flow of 21.9 liters per seconds (l/s) (0 .5 mgd). The principal features of the plant included influent pumping, primary sedimentation and oxidation ponding. Sludge was treated with anaerobic digesters and drying beds.

As part of the long-range plan for sewerage facilities in the Santa Rosa Plain, construction of the Laguna Treatment Plant was recommended in a 1962 engineering report for the County of Sonoma entitled, "Collection, Treatment, and Disposal of Sewage and Industrial Wastes Within the Santa Rosa Plain" by M. Carleton Yoder, Consulting Engineer. It was also recommended that Rohnert Park and Cotati tie in with the proposed facility. In the regional plan, all wastewater south of Mark West Creek (see Figure 1) would go to the Laguna Regional Plant. This would cover the existing area presently sewered to the cities of Sebastopol, Santa Rosa, Rohnert Park and Cotati. In 1967, Stage 1 Construction of the Laguna Regional Wastewater Treatment Plant was completed by the city of Santa Rosa. It had an initial capacity of 110 l/s (2.5 mgd).

By 1966, increased growth and the addition of the newly constructed California State College Sonoma to the Rohnert Park Sewerage System was causing the original Rohnert Park treatment facilities to be overloaded. A study made for the City of Rohnert Park in 1966 entitled "Wastewater Collection, Treatment and Disposal" by M. Carleton Yoder Associates, Consulting Engineers, indicated that it was not economically feasible to transport Rohnert Park wastewater to the Laguna Regional Treatment Plant at that time. However, the report

Figure 1. Laguna de Santa Rosa Area



recommended that a re-evaluation of the feasibility of connecting to the Laguna Plant be made at the time that the next expansion of the city's treatment facilities was required.

One of the main factors of concern to the design of treatment and disposal facilities at Rohnert Park was the high wet weather wastewater flows encountered during the rainy season. Although detailed data were not available, it was estimated that peak wet weather flows exceeded average dry weather flows by as much as eight to ten times.

At this point in time, the idea of the unique surge facility was presented to the Federal Water Pollution Control Administration (now EPA) in the form of a grant request. The surge facility would be used for two principal functions. The first would be to provide flow equalization and some degree of treatment to all storm flows regardless of flow rate. The second would be to provide rate control of all dry weather flows to the interceptor sewer. The initial request was for a project which covered both the surge facility and the transmission line to the regional treatment plant. As a result of discussions and correspondence with FWPCA, the original grant request was revised. The Demonstration Project, as revised, included the surge facility but not the transmission lines. It was felt that the knowledge gained through operation of the surge facility would be used to design the optimum system for transporting the wastewater to the Regional Plant, thus resulting in a considerable savings in costs of regionalization.

The uniqueness of the Rohnert Park Surge Facility was in the method of sludge removal from the surge basin. For this particular facility, an attempt was made to show that Pool Sweeps, an item normally used for cleaning the bottom of swimming pools, could be adapted to a small surge facility in order to maintain the flow of solids through the basin.

The primary objectives, or areas of investigation, of the demonstration period as originally outlined in the Demonstration Project proposal included: 1) research and development on the sludge collection and removal system; 2) studies of primary sedimentation tank (clarifier) efficiencies comparing variable versus uniform flow conditions; 3) economic evaluation of the proposed surge facility as compared to conventional alternatives for transporting and treating local wastewater including capital and O&M costs; and 4) evaluation of possible application of the Rohnert Park system to other regional wastewater collection plans.

In order to make the most meaningful evaluation of relative costs for transporting and treating regulated or controlled flows versus normal variable flows, and to show the potential use of this type of facility for an entire regional wastewater

facility, it was decided to make the economic comparison of alternatives specifically for the Santa Rosa Plains regional area of which Rohnert Park is a part.

Implementation of the Demonstration Project by the City of Rohnert Park covered the following periods. The design was accomplished during the period from January 1970 through May 1970. The construction took approximately twelve months and was completed in May 1971. The actual demonstration period began in July 1971 and ended in February 1973.

# SECTION IV

# PROJECT FACILITIES

## DESIGN OBJECTIVES

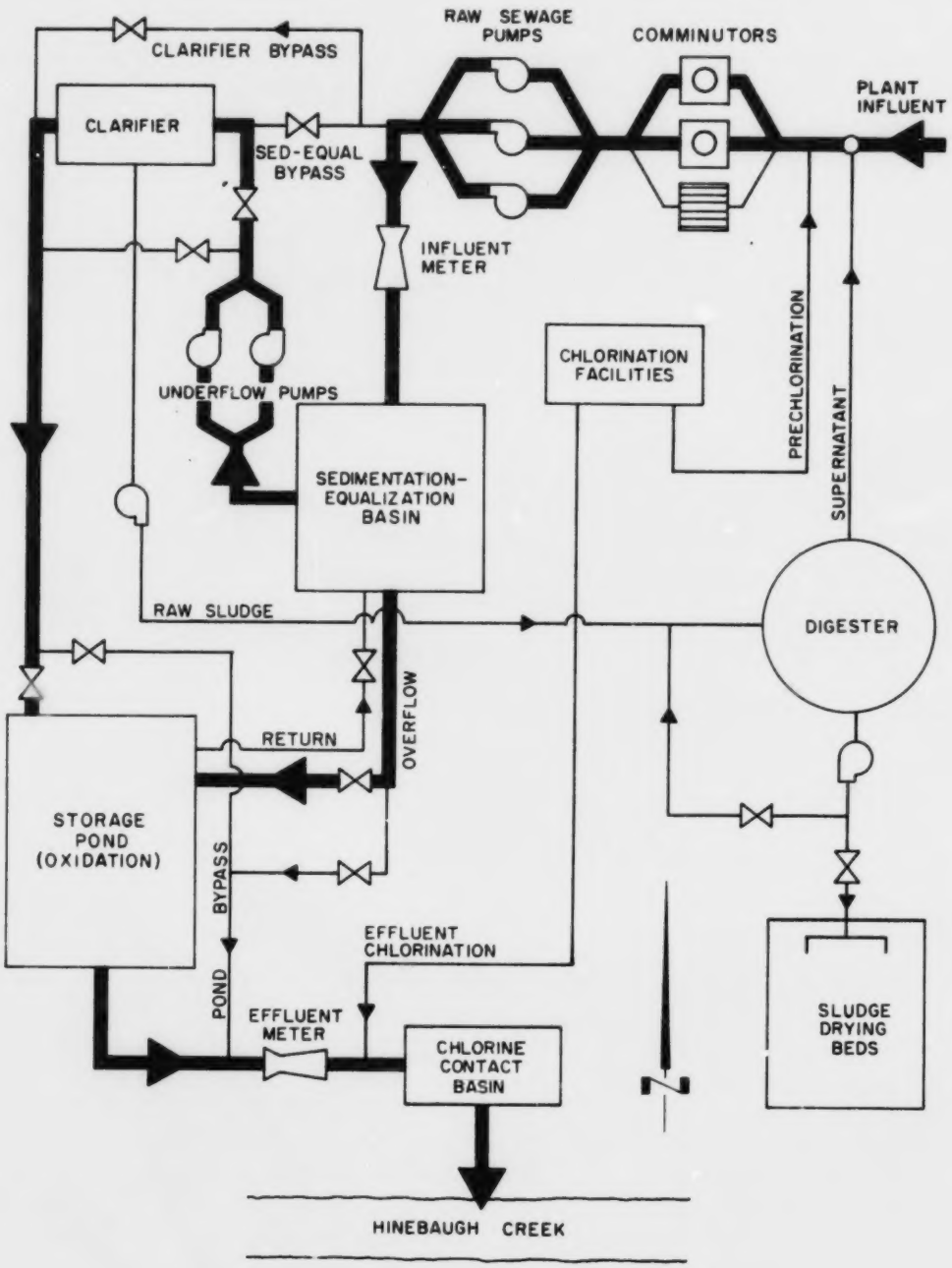
The design objective for the Demonstration Project was to provide a surge facility which would remove the normal dry weather peaks which occur in wastewater flows and the peaks which occur due to wet weather infiltration/inflow, and thus, provide a uniform flow to a regional treatment plant system. As is the case with all surge facilities, one of the major problems encountered is the settlement of sewage solids on the bottom of the storage facility. The Rohnert Park Demonstration Project was designed to test a method whereby these solids can be prevented from accumulating on the bottom of an inexpensive earthen, lined basin without the use of conventional mechanical sludge collection equipment.

## GENERAL FLOW SHEET DESCRIPTION

The general flow pattern is shown in Figure 2 and is described below. All wastewater enters the plant from the east into the pump station which contains the treatment plant headworks and raw sewage pumping facilities. From there the raw sewage is pumped to the influent metering and sampling station from which it flows by gravity to the center of the Sedimentation-Equalization Basin. The underflow from the basin is pumped by the underflow pumps located in the basement of the control building to the clarifier. The underflow from the clarifier goes to the digester and the effluent from the clarifier goes to the storage pond. The overflow from the Sedimentation-Equalization Basin goes by gravity directly to the storage pond, and by opening a gate in the overflow structure, the overflow can be returned to the basin from the storage pond. All flows which overflow the storage pond go through the effluent metering and sampling station and chlorination facilities prior to discharge.

As used in this report, the term "surge facility" represents the total facility including raw sewage pump, Sedimentation-Equalization Basin, underflow pumping, storage pond and overflow chlorination, whereas the term "Sedimentation-Equalization Basin" refers only to the basin itself along with the associated influent pipe, Pool Sweeps, aerator, overflow structure and skimming structure.

Figure 2. Demonstration Project Flow Sheet



## DESIGN AND OPERATIONAL PARAMETERS

To acquaint the reader with the Rohnert Park facilities, this section discusses the design and operational parameters of the major components of the facilities. The major components of the system include: 1) influent pump station; 2) influent metering and sampling; 3) Sedimentation-Equalization Basin; 4) control building; 5) underflow pumping facilities; 6) clarifier; 7) storage pond; 8) effluent metering and sampling; and 9) chlorination facilities.

### Influent Pump Station

The influent pump station contains two comminutors, an eight-inch pump with a 25 hp fixed speed motor and two six-inch pumps with 20 hp variable speed motors. The total pumping capacity of the raw sewage pumps is 263 liters per second (l/s) (6 mgd).

### Influent Metering and Sampling

The influent metering structure is a Parshall flume with a one-foot throat width having a maximum capacity of approximately 350 l/s (8 mgd). The influent sampler is a flow proportional sampler controlled by either a hand-set electric timer or by a signal from the influent flow transmitter. The sample is continuously pumped through the sampler from immediately ahead of the Parshall flume.

### Sedimentation-Equalization Basin

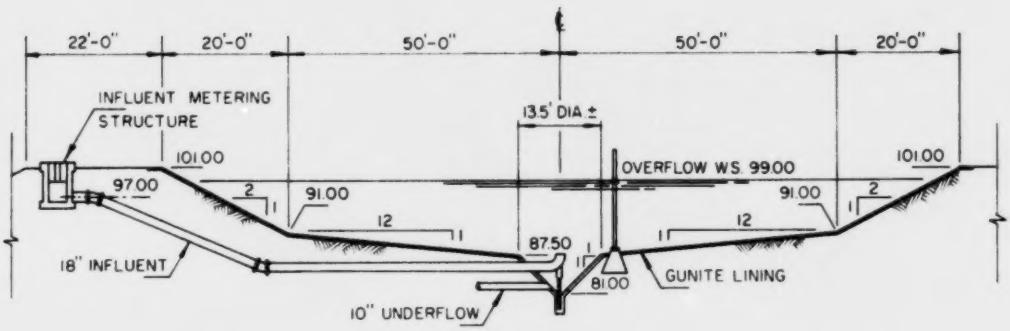
This basin is the principal component of the Demonstration Project. The major components of the basin, some of which are shown in Figures 3 and 4, include: 1) basic configuration; 2) influent pipe; 3) aerator; 4) Pool Sweeps; 5) overflow structure; and 6) skimming structure.

### Basic Configuration -

The basin shown in Figures 3 and 4 is an earthen structure lined with gunite. Gunite was chosen because it is relatively inexpensive and is quite durable from the application tested. The use of the "rigid" liner did cause some initial problems during construction, however. The native soils used for the embankments were quited expensive and were not thoroughly wetted prior to installation of the gunite. When the basin was filled for the first time, the expanding soil buckled the lining. Once repaired, no further movement was observed. When full, it has a capacity of 2,841 cubic meters (cu m) (0.75 million gallons) and a minimum detention time of three hours based on the design maximum flow of 263 l/s (6 mgd). The side slopes are 2:1, and the bottom slope is approximately 12:1 toward the center. The center sump is cone-shaped

Figure 3. Sedimentation-Equalization Basin

Figure 4. Basin Cross Section



and is 13-1/2 feet in diameter at the top and 6-1/2 feet deep. The overall diameter of the basin to the centerline of the levees is 152 feet. The approximate diameter of the water surface at elevation 99.0 is 132 feet.

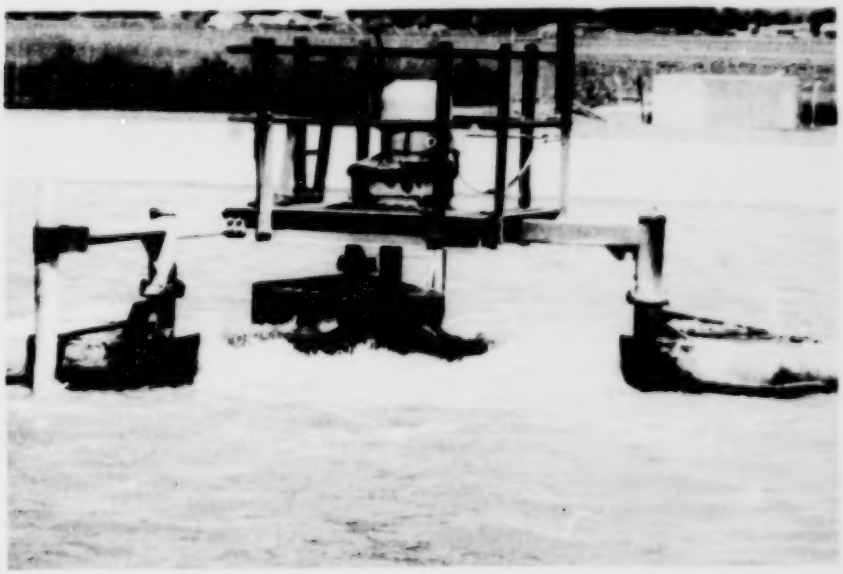
Influent Pipe -

The influent to the basin discharges vertically upward in the center of the basin immediately under the floating aerator at approximate elevation 87.5.

Aerator -

This unit is a floating surface aerator which is held in position by the two vertical pipes. The aerator is shown in Figure 5. For this application, the aerator was designed just to maintain a residual dissolved oxygen (DO) in the Sedimentation-Equalization Basin during the normal or dry weather flow periods. The objective of the aeration was to prevent septicity and the resulting odors. The 15 hp aerator in the 2,841 cu m (0.75 mg) basin provides 0.15 hp per 1,000 cu. ft. of tank volume whereas a range of 0.5 to 1.0 hp per 1,000 cu. ft. is generally required to maintain a completely mixed basin. The exact ratio will depend on basin design parameters such as surface area, depth, waste strength, etc.

Figure 5. Floating Aerator



Pool Sweeps -

The Pool Sweeps are shown in Figures 6, 7 and 8. Figure 6 is a schematic diagram showing all of the major components of the unit. Figure 7 shows a unit operating in the Sedimentation-Equalization Basin. Note the "tethering" effect of the main supply hose which is attached to the water supply outlet at the periphery of the basin. Figure 8 shows the unit out of water and indicates the relative length of the normal sweep hoses and the modified single hose, with "wye" assembly, which was used during a portion of the demonstration period. For the Demonstration Project, the Pool Sweeps were used in an attempt to maintain the flow of solids through the basin. The water supply outlets for the three Pool Sweeps used during the major portion of the testing period were evenly spaced around the periphery of the Sedimentation-Equalization Basin. The major components of the Pool Sweep are: 1) the main body which contains all of the water pressure operated valves and gears; 2) the thrusters (back and front) which give it mobility in open water; 3) the bottom rotating ring which gives it mobility when it comes in contact with a vertical or sloped wall; 4) the water supply line which delivers approximately 1.25 l/s (20 gpm) at 3.5 $kgf/cm^2$ (50 psi) to the main body; 5) the side wall hose (shorter) and the bottom hose (longer) which provide the agitation to the solids which settle to the bottom and sides of the basin; 6) the top spray jet which, when used in a swimming pool, washes the vertical side walls; and 7) the main jets in the extreme ends of the side wall and bottom hoses.

The water supply intake for the Pool Sweeps was obtained from the effluent end of the clarifier just under the water surface. The primary effluent was then pumped into a loop supply system in the top of the basin levee. When first placed in service, frequent plugging of the main valving of the Pool Sweep body, by small pieces of plastic, primarily, required that a cleaner water supply be found.

Because we felt it would yield useful information to operate the units on a wastewater supply, we devised a PVC pipe suction screen to remove all material which could plug the units. The suction screen, shown in Figure 9, was made from a one meter (approximately 3 feet) length of PVC pipe which was perforated along its entire length with one-inch diameter holes and wrapped with a fine screen. The screen could be raised and cleaned easily and put back in service quickly. With the quality of primary effluent being used, the Pool Sweeps could be operated continuously for approximately 48 hours before the screen required cleaning.

Overflow Structure -

The overflow structure shown at the far corner of Figure 3 and in Figure 10 has four sharp-crested rectangular weirs, totaling 1.42 meters (8 feet, 4 inches), set at

Figure 6. Pool Sweep Schematic Diagram

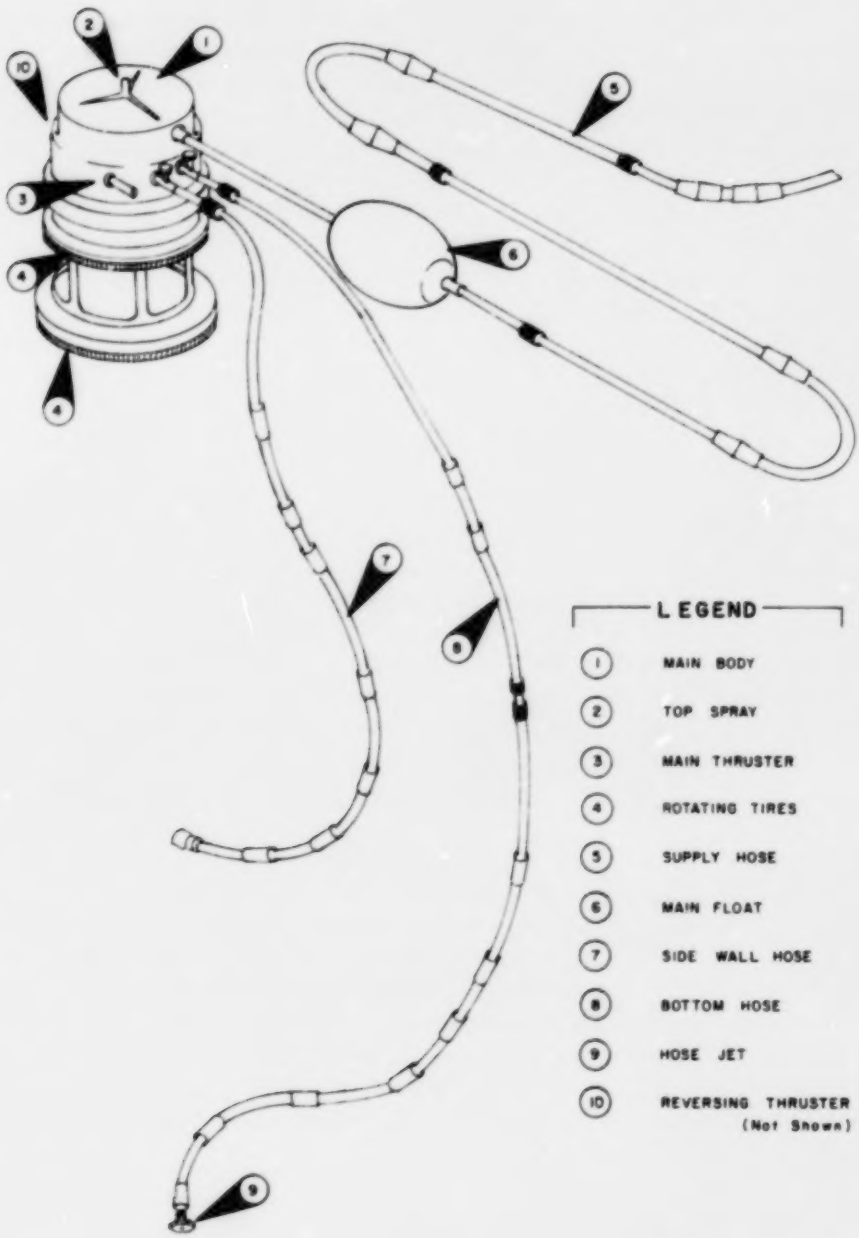


Figure 7. Pool Sweep in Operation

Figure 8. Pool Sweep with Hoses

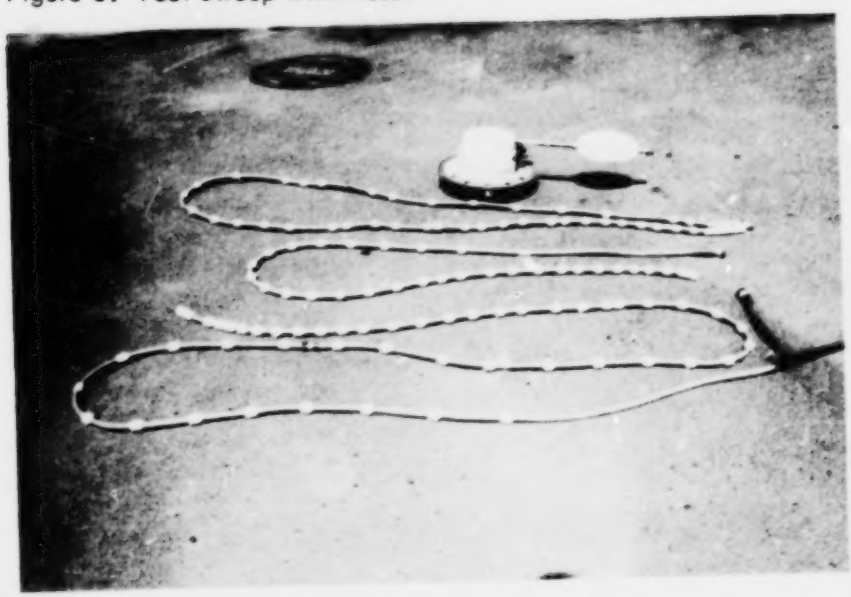


Figure 9. Pool Sweep Water Supply Suction Screen

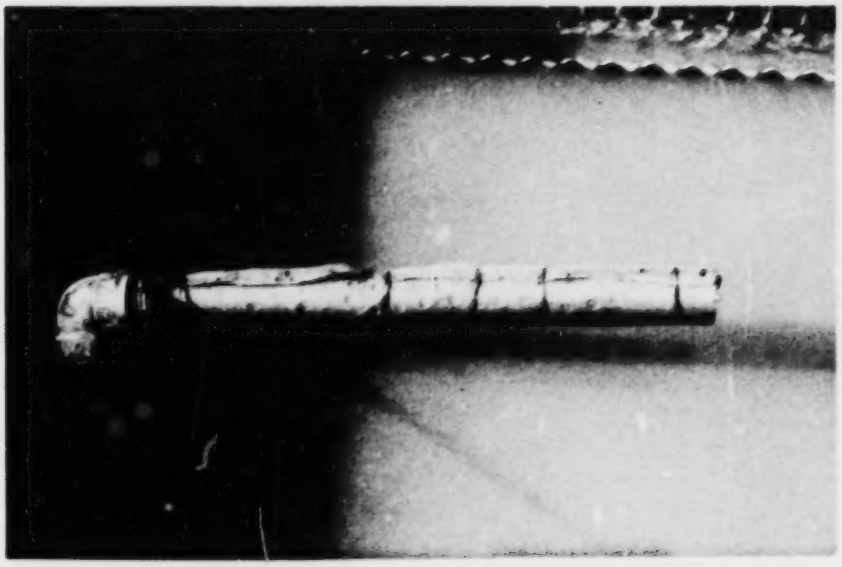
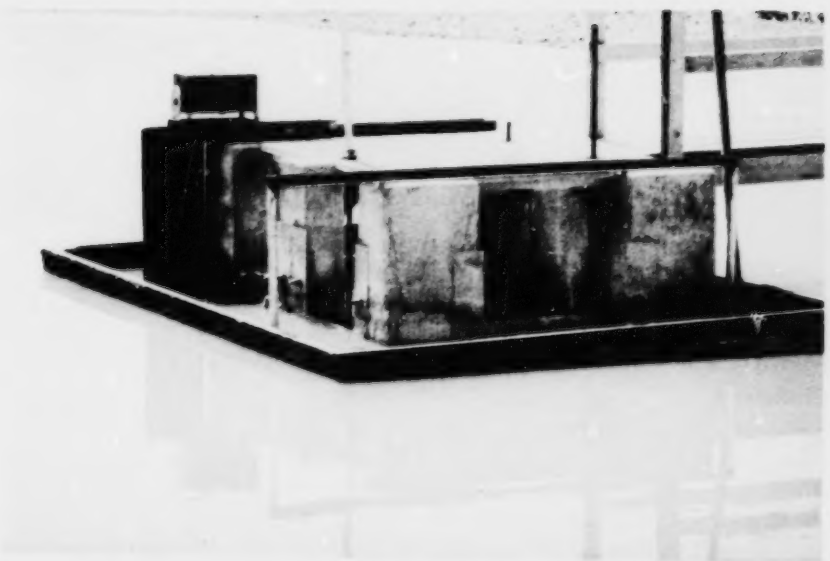


Figure 10. Overflow Structure



elevation 99.0. Each weir is independently adjustable over a 0.11 meter (4-inch) vertical range. The overflow structure was designed to bypass all flows in excess of the underflow up to a maximum of 263 l/s (6.0 mgd) directly to the storage pond.

To monitor the water surface fluctuations in the Sedimentation-Equalization Basin, a float-operated, portable stage recording device was added to the overflow structure. The recorder was a Stevens type "F" with interchangeable stage and time gears. For this project, we selected time gears which gave an 8-day chart and stage gears which gave an indication of 0.5 foot per inch of chart or 0.1 foot per inch of chart depending on the depth variation expected during any particular testing period.

Skimming Structure -

The skimming structure shown in Figure 11 and previously shown in Figure 7 was designed to facilitate the removal of floating scum and grease in the Sedimentation-Equalization Basin. The underflow pumps were valved so that they could draw from the skimming structure. Stop logs were used to control the amount of overflow into the box while skimming. The skimming structure could also be used as a side drawoff for the basin underflow, if needed.

Figure 11. Skimming Structure

## Control Building

The control building houses the operator's desk, the underflow pump controls, all of the plant metering and recording instruments, the chlorination equipment, and the laboratory. The laboratory was equipped to do all of the tests necessary for the Demonstration Project and for operating the treatment plant with the exception of the bacteriological tests.

## Underflow Pumping Facilities

The flow out of the bottom of the Sedimentation-Equalization Basin is pumped by the underflow pumps located in the basement of the control building. The underflow pumping facilities consist of two 4-inch pumps with belt-driven variable speed drives. The suction for the underflow pumps draws from the bottom of the center sump of the Sedimentation-Equalization Basin. The pumps discharge into a single manifold and a 6-inch magnetic flowmeter. The underflow can be set at any desired rate up to 100 l/s (2.3 mgd). When the surge facility becomes part of a regional sewerage system the underflow pumps will discharge into an interceptor to the regional treatment plant. During the Demonstration Project, however, the underflow, which contained the raw sludge from the incoming flow, went to the clarifier.

## Clarifier

The clarifier used during the Demonstration Project was a typical primary clarifier operated in the normal manner. The clarifier had a design capacity of 22 l/s (0.5 mgd) based on the conventional design criteria of a 2-hour detention time and a 32.61 cu m per square meter per day ($m^3/m^2/day$) (800 gallons per day per square foot, gpdsf) overflow or rise rate. The clarifier influent came from the underflow pumps and the effluent normally went to the northeast corner of the storage pond. The bottom sludge went to the 10.37 meter (34-foot) diameter digester and ultimately to sand drying beds.

## Storage Pond

The existing 4.86 hectare (12-acre) by 1 meter (3-foot) deep oxidation pond, which was part of the original treatment plant, was intended in the demonstration to be a storage pond which would collect and store all of the winter peak flows which overflowed the Sedimentation-Equalization Basin. During the normal dry weather periods, the original plan was to bypass the storage pond and keep it empty until it was needed for winter storm flow storage. The effluent from the clarifier would go directly to chlorination facilities and then be discharged.

### Effluent Metering and Sampling

The effluent metering structure contains a 0.16 meter (6-inch) Parshall flume and a 1.48 meter (4-foot, 6-inch) sharp-crested rectangular weir. The two flow measuring devices are set to give a combined capacity of 263 l/s (6 mgd) at a pond elevation of 98.05; i.e., when the Parshall flume has 0.43 meters (1.3 foot) of head on it and when the resulting head on the weir is 0.18 meters (0.55 foot). The effluent sampler is a flow proportional sampler controlled by either a hand-set electric timer or by a signal from the effluent flow transmitter. The sample is taken from a waste stream which is continuously pumped through the sampler from immediately ahead of the Parshall flume.

### Chlorination Facilities

The chlorination facilities consist of two flow paced chlorinators which normally work in parallel, one for prechlorination and one for post-chlorination. They are interconnected through a manifold assembly so that each is a backup for the other. The post-chlorination facilities at the effluent metering location consist of a solution distribution manifold, a baffled concrete mixing chamber and an earthen contact pond which provides approximately 20 minutes' contact time at the design maximum flow before the effluent enters the 305 m (1,000 ft.) of outfall line. All flows which leave the plant are measured and chlorinated prior to discharge.

## PRINCIPAL MODES OF OPERATION

As originally envisioned, there would be two principal modes of operation for the surge facility. There would be the dry weather flow plan of operation and the wet weather flow plan of operation. Both modes of operation are represented in their respective flow diagrams shown in Figures 12 and 13. The principal objectives of the dry weather flow program were to determine the hydraulic control available to the system for the daily flow variations; to determine the partial treatment obtained with this type of facility during the detention process; to determine the effect of the basin on subsequent treatment processes; and to determine the effectiveness of the Pool Sweep mode of operation in the control of solids movement through the surge facility. The principal objectives of the wet weather flow operation were to determine the hydraulic control characteristics at the higher peak flow rates encountered in the winter; to determine the quality of overflow from the Sedimentation-Equalization Basin to the larger storage facility; to determine the effectiveness of the Pool Sweep mode of operation during the periods of peak flow through the Sedimentation-Equalization Basin, and to determine the probable storage requirements, both in size and configuration.

Figure 12. Dry Weather Flow Diagram

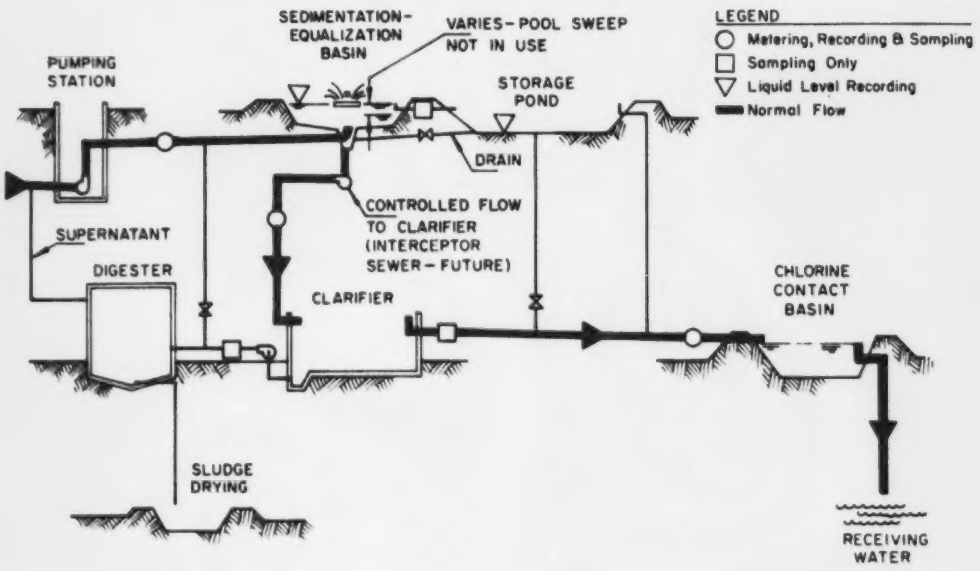
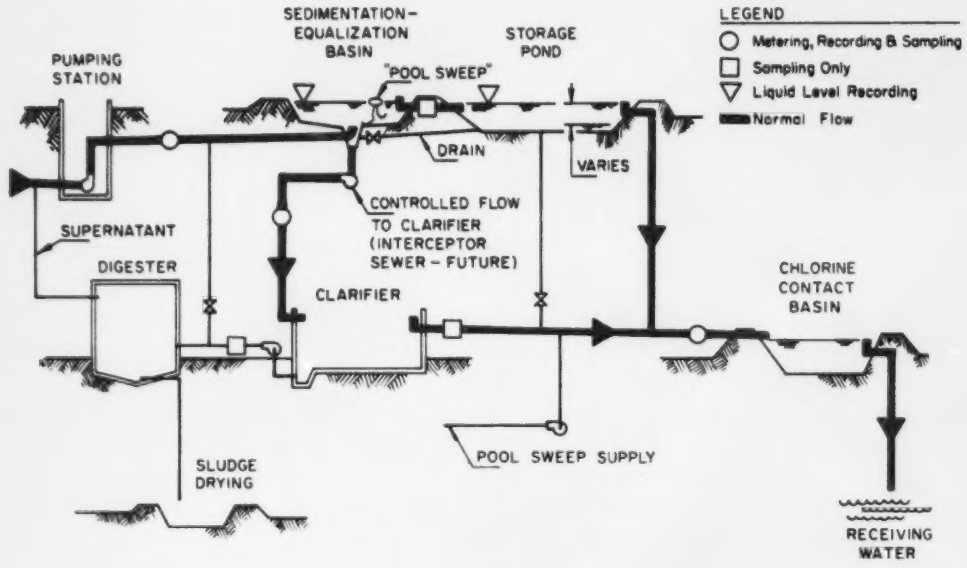



Figure 13. Wet Weather Flow Diagram



Just prior to the completion of construction of the Demonstration Project facilities, Rohnert Park's waste discharge requirements were revised and upgraded by the State of California Regional Water Quality Control Board. The new requirements precluded the discharge of primary effluent, and therefore, did not allow the diversions of flow around the 4.86 hectare (12-acre) storage pond. To obtain the wastewater quality required, all flows had to be given an additional level of treatment by operating the storage pond as a conventional oxidation pond. The determination of potential operational problems due to the intermittent filling and drying of the storage pond was, therefore, not possible.

# SECTION V

# TESTING AND EVALUATION

The Demonstration Project testing covered the period from July 1971 to February 1973. The first two tests, listed as A and B, were begun soon after construction was completed. The major objectives of these tests were to evaluate the hydraulic control capability and flexibility of the surge facility and to evaluate the relative efficiency of the primary clarifier when used in the normal way or when used following a surge basin. Tests A and B were made under dry weather mode of operation as discussed in Section IV.

The second set of tests, listed as C and D, were made during the first winter of the demonstration period (1971-72). They were made using the wet weather mode of operation, also discussed in Section IV. The very dry winter and subsequent very low flows during this winter resulted in almost no overflow. For this reason these two tests are discussed under the heading "Dry Weather Testing."

The third set of tests, numbered 1 through 4, were used to study the overall operation of the surge facility and, in particular, the solids flow through the basin and the Pool Sweep operation. These four tests were also made using the wet weather mode of operation. The tests were run during a "dry weather" period, however, and an overflow was produced by lowering the underflow rate to approximately 75 percent of the average dry weather flow. For this reason, tests 1 through 4 are discussed under the heading "Dry Weather Testing."

The last set of tests, numbered 5 through 9, represent the testing performed under wet weather flow conditions. They were used to study the overall operational characteristics of the surge facility under heavy or peak flow conditions and, in particular, the solids flow through the basin.

To simplify the identification of each of the tests, Table 1 gives a summary of the pertinent data for each test.

## DRY WEATHER TESTING

### Test A

The primary objective of Test A was to provide a trial period of operation to test the capability and flexibility of the hydraulic control of the surge facility. Principally, we wanted to achieve the operation of the Sedimentation-Equalization Basin at a constant underflow rate 24 hours per day accommodating the normal

Table 1. SUMMARY - BASIC TEST PARAMETERS

| Test No. | Maximum flow rates | | | Aerator | Pool Sweeps | Average influent characteristics[d] | | |
|---|---|---|---|---|---|---|---|---|
| | Influent, l/s[a] | Underflow,[b] l/s | Overflow, l/s | | | Settleable Solids ml/l/hr | Suspended Solids mg/l | BOD, mg/l |
| Dry Weather Testing | | | | | | | | |
| A | 52.5[c] | 52.5 | 0 | On | On | 9.2 | 264 | 274 |
| B | 69.4 | - | - | On | On | 8.6 | 250 | 224 |
| C | 84.5 | 51.7 | 32.8 | Off | On | 10.8 | 305 | - |
| $D_1$ | 52.5[c] | 36.3 | 16.2[c] | Off | On | 6.0 | 194 | 193 |
| $D_2$ | 54.7[c] | 41.6 | 13.1[c] | On & Off | On | 9.8 | 227 | 202 |
| 1 | 82.0 | 35.0 | 47.0 | Off | On | 7.87 | 167 | 149 |
| 2 | 82.0 | 35.0 | 47.0 | Off | On | 13.25 | 130 | 270 |
| 3 | 75.7 | 35.0 | 40.7 | Off | Off | 11.77 | 159 | 238 |
| 4 | - | 32.8 | - | Off | On | - | - | - |
| Storm Flow Testing | | | | | | | | |
| 5 | 126 | 37.8 | 88.2 | Off | On | 7.50 | 82 | 258 |
| 6 | - | 39.4 | - | Off | On | - | - | - |
| 7 | 170.3 | 39.7 | 130.6 | Off | On | 4.46 | 79 | 134 |
| 8 | 242.9 | 37.8 | 205.1 | Off | On | 3.25 | 133 | - |
| 9 | 239.7 | 37.8 | 201.9 | Off | On | 3.71 | 104 | 70 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm).
[b] Underflow remained constant during tests.
[c] Average values are given instead of maximums.
[d] Averages shown are for 6 to 22 data points for Tests A through $D_2$; 10 to 24 data points for Tests 1 through 4; and 7 to 12 data points for Tests 5 through 9.

daily influent variation while maintaining the water surface elevation within acceptable limits. Acceptable limits were considered not high enough to cause an overflow and not low enough to affect the operation of the aerator.

By observing the influent and underflow flowmeters in conjunction with the Sedimentation-Equalization Basin stage recorder, it was possible to adjust the underflow pumps to provide a constant underflow rate out of the basin while accommodating the daily flow variations. It was found that a total daily water surface fluctuation of less than two feet at approximate elevations 96 to 98 (one to two feet below overflow) was required to produce the desired result.

Table 2 shows the results of tests performed on 22 days during the months of August and September 1971.

Table 2. TEST A - AVERAGE WASTE STRENGTH OF VARIOUS FLOWS

| Characteristics | Influent | Underflow | Clarifier effluent | Storage pond effluent |
|---|---|---|---|---|
| Q avg., l/s[a] | 52.5 | | | |
| DO, mg/l | 0.0 | 0.3 | 0.1 | 5.4 |
| Settleable Solids, ml/l/hr | 9.2 | 7.4 | 0.4 | 0.1 |
| Suspended Solids, mg/l | 264 | 244 | 120 | 76 |
| BOD, mg/l | 274 | 228 | 128 | 59 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

Test A evaluated: 1) the average characteristics of the raw wastewater (BOD, DO, flow, Suspended Solids, and Settleable Solids); 2) the change in wastewater characteristics through the Sedimentation-Equalization Basin; 3) the treatment efficiency of the primary clarifier under conditions of constant flow from the bottom of the Sedimentation-Equalization Basin; and 4) the observable effects of the Pool Sweep operation.

During this testing period, the detention time in the Sedimentation-Equalization Basin was about 10 to 12 hours and the aerator was operated the major portion of the time. The underflow rate was set to eliminate any overflow from the basin.

The test results shown in Table 2 indicate the following average changes in the wastewater characteristics as a result of flowing through the Sedimentation-Equalization Basin: 1) 17% BOD reduction; 2) 15% Suspended Solids reduction; and 3) 20% Settleable Solids reduction.

Under the condition of uniform flow, the clarifier was able to remove an average of 44% of the BOD, 50% of the Suspended Solids, and 94% of the Settleable Solids. The hydraulic loading on the clarifier at a flow rate of 52.5 l/s (1.2 mgd) was 75.42 $m^3/m^2/day$ (1,850 gpdsf), more than twice the design rate of 32.61 $m^3/m^2/day$ (800 gpdsf).

The total removal through the Sedimentation-Equalization Basin and the clarifier was, therefore, 53% BOD, 55% Suspended Solids, and 95% Settleable Solids.

During the initial testing period, the Pool Sweeps went through a trial period in which the nozzle jet size was varied to obtain the optimum combination of water volume, pressure and velocity at the end of the floor and wall hoses.

Preliminary observation of the Pool Sweep operation without the aerator indicated that the action of the hoses "sweeping" the bottom of the basin was helping to prevent the buildup of solids. The floating portion of the Pool Sweep unit, however, did not appear to cover as wide an area or follow as arbitrary a path as did the same units in a swimming pool. The main reason for this appeared to be the fact that in a swimming pool the Pool Sweep supply hose is long enough to allow the floating head to hit and run along the vertical sides, but, in our application, the floating head is "tethered," that is, restrained by the supply hose rather than the vertical walls. Subsequent to these tests, several modifications were made to the internal valving of the drive jets. None of the modifications proved to better the operation of the sweeps, however. Recurring plugging of the internal valves in the floating head of the Pool Sweep proved to be one of the major problems associated with the use of a primary effluent for the water supply.

Our experience would indicate that a water of secondary effluent quality or better is required to operate the sweeps without plugging. It was later found that the high concentration of grease in a primary effluent also caused a buildup within the main body of the Pool Sweep which was detrimental to their operation and required frequent maintenance.

## Test B

Test B included the development of background data for future evaluation of the Sedimentation-Equalization Basin. A specific objective was to establish the treatment efficiency of the primary clarifier under the normal conditions of variable hydraulic and solids loading rates. To accomplish this, the raw sewage was bypassed around the Sedimentation-Equalization Basin directly to the clarifier. During the testing period, the flow rate through the clarifier varied from 18.9 to 69.4 l/s (300 to 1,100 gpm) representing surface loading rates of 27.92 to 101.92 $m^3/m^2$/day (685 to 2,500 gpdsf). In general, the flow remained above 50.5 l/s (800 gpm) between the hours of 10:00 a.m. and 10:00 p.m.

Based on the results of six tests made in October 1971, under the above conditions, Test B gave the following results in terms of removal efficiencies through the clarifier: BOD--65%; Suspended Solids--61%; and Settleable Solids--93%. The removal efficiences for BOD and Suspended Solids were higher than expected based on the results of previous tests of clarifier performance when the flow first passed through the Sedimentation-Equalization Basin. A possible explanation for this was the action of the aerator and the resulting attrition of the solids as they passed through the Sedimentation-Equalization Basin. The agitation the waste receives from the surface aerator probably changes the form of the solids from larger to smaller and to more soluble forms, also. These would cause the lower values for Settleable Solids measured in previous tests. The difference is small, however.

Throughout Test B, we continued to have a plugging problem with the Pool Sweep units which was attributed to the supply water. Prior to Test C, a special screening device for the Pool Sweep water supply was placed in operation. Using this device, we were able to operate all the Pool Sweeps continuously for approximately 48 hours. Less than ten minutes was required for one man to clean the device and place it back in service.

## Test C

For Test C, the Demonstration Project facilities were operated according to the wet weather mode of operation previously shown in Figure 13. However, due to the unusually dry winter and subsequent low storm flows in the wastewater collection system, the Sedimentation-Equalization Basin overflowed only twice and then only a small amount. Under the above conditions of practically no overflow, additional tests were made to evaluate the changes in the characteristics of the sewage as it passed through the Sedimentation-Equalization Basin. During a testing period in late December 1971 when: 1) 2.6 inches of rain fell; 2) the aerator remained off except for very short periods; 3) the inflow varied from 42.9 to 84.5 l/s (0.98 to 1.93 mgd) and averaged 48.2 l/s (1.10 mgd); and

5) the Pool Sweeps remained on continuously, the following average changes were documented.

Based on the average results of seven tests made on December 20 through December 27, 1971, the Settleable Solids were reduced by 24% as the flow passed through the Sedimentation-Equalization Basin and the remaining Settleable Solids in the underflow were reduced by 97% in the clarifier. The Suspended Solids were reduced by 7.4% as the flow passed through the Sedimentation-Equalization Basin and the remaining Suspended Solids were reduced by 59% in the clarifier. The BOD was not measured for Test C. These results indicate that either there was an accumulation of solids in the basin or there was an attrition of solids taking place in the basin or both.

Tests $D_1$ and $D_2$

Prior to Tests $D_1$ and $D_2$, in mid-January 1972, the operational procedures of the surge facility were modified slightly. By reducing the underflow rate to 35.0 l/s (0.8 mgd) an average overflow rate of approximately 13.1 l/s (0.3 mgd) was produced. The remainder of the operational schedule remained the same, as did the sampling and testing program. During two separate periods in the last part of January and in February, tests were conducted to provide information on the operational characteristics of the Sedimentation-Equalization Basin under overflow conditions. The primary objectives of these two tests were the evaluation of overflow quality in relation to influent quality and the evaluation of the quantity of solids remaining in the basin. Table 3 summarizes the results of eight tests made between January 22 and January 31, 1972.

Table 3. TEST $D_1$ - AVERAGE WASTE STRENGTHS OF VARIOUS FLOWS

| Characteristics | Influent | Underflow | Overflow |
|---|---|---|---|
| Q avg., l/s[a] | 52.5 | 36.3 | 16.2 |
| BOD, mg/l | 193 | 167 | 110 |
| Suspended Solids, mg/l | 194 | 159 | 84 |
| Settleable Solids, ml/l/hr | 6.0 | 5.5 | 0.3 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

The data summarized above are for those days when the aerator was off. In terms of quality (mg/l), the overflow contained only 57% of the influent BOD, 43% of the influent Suspended Solids, and 5% of the influent Settleable Solids.

In Test $D_1$, a mass balance of BOD and Suspended Solids through the Sedimentation-Equalization Basin made by multiplying the flow rate times the waste strength, gives a clear indication of the buildup of solids in the basin. Using the data presented in Table 3, the mass balances indicate that 60% of the influent BOD and 57% of the influent Suspended Solids were removed in the underflow. At the same time, 18% of the influent BOD and 13% of the influent Suspended Solids were removed in the overflow. This means that 22% of the BOD and 30% of the Suspended Solids remained in the basin during the test period, and/or there were sampling/analytical inaccuracies.

Table 4 summarizes the results of seven tests with the aerator on and seven tests with the aerator off during the period from February 14 through February 28, 1972.

Table 4. TEST $D_2$ -AVERAGE WASTE STRENGTHS OF VARIOUS FLOWS

| Characteristics | Influent | | Underflow | | Overflow | |
|---|---|---|---|---|---|---|
| | Aer. off | Aer. on | Aer. off | Aer. on | Aer. off | Aer. on |
| Q avg., l/s[a] | 54.7 | 54.7 | 41.6 | 41.6 | 13.1 | 13.1 |
| BOD, mg/l | 202 | 198 | | | 96 | 176 [b] |
| Suspended Solids, mg/l | 227 | 219 | | | 113 | 199 [b] |
| Settleable Solids, ml/l/hr | 9.8 | 6.8 | | | 0.4 | 3.9[b] |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

[b] The operator fears that high grease concentrations were interfering with these test results.

As can be seen from Table 4, the test results with the aerator off were fairly consistent with the results of Test $D_1$. That is, the overflow contained 47% of the influent BOD concentration (mg/l), 50% of the influent Suspended Solids concentration, and 4% of the influent Settleable Solids concentration.

The effects of leaving the aerator on during the periods when the Sedimentation-Equalization Basin is overflowing to the storage pond are shown in the second set of data in Table 4. The mixing action of the surface aerator reduced the effectiveness of the Sedimentation-Equalization Basin to remove solids prior to overflow. Under these conditions, the overflow contained 57% of the influent BOD concentration (mg/l) as compared to 47% with the aerator off; the overflow contained 89% of the influent Suspended Solids concentration as compared to 50% with the aerator off; and the overflow contained 57% of the influent Settleable Solids concentration as compared to 4% with the aerator off. These data clearly show that the aerator must be left off to allow the basin to remove the greatest amount of solids prior to overflow to the overflow storage pond.

Test No. 1

Test No. 1 was the first comprehensive test which involved the sampling of all flows into and out of the Sedimentation-Equalization Basin on an hourly basis for a complete 24-hour period. During the testing period, the aerator was not operated at all and the Pool Sweeps were operated continuously. Samples were taken at the basin influent metering channel, the clarifier influent channel (basin underflow), and the basin overflow structure. Each sample was analyzed for DO, BOD, Settleable Solids, and Suspended Solids. A graphical presentation of the results are shown in Figure 14.

The relationship of the Settleable Solids with time at the three sampling points shows that there was a marked decrease in the Settleable Solids concentration between influent and underflow. The two most probable explanations for this are an attrition of solids, and a net accumulation of large or heavy solids in the basin. The curves show that during the low flow period from about 2:00 a.m. to 7:00 a.m., the solids concentration in the underflow remained below those in the influent. This indicates that the solids which accumulated on the basin floor during the higher flow period were not being removed as we had anticipated. The overflow Settleable Solids concentrations were quite low throughout the time that overflow occurred.

The relationship of the Suspended Solids with time at the three sampling points shows that during the higher flow periods the underflow contained a lower solids concentration than the influent, but during the lower flow period, the underflow concentration was higher than the influent. The overflow remained considerably lower in solids than the influent or underflow.

Comparing Settleable and Suspended Solids data it appears that the heavier, larger Settleable Solids are accumulating in the basin while the lighter, smaller solids are more effectively being removed by the action of the Pool Sweeps or the flow patterns set up by the basin underflow or both,

Figure 14. Test No. 1 Concentration Curves

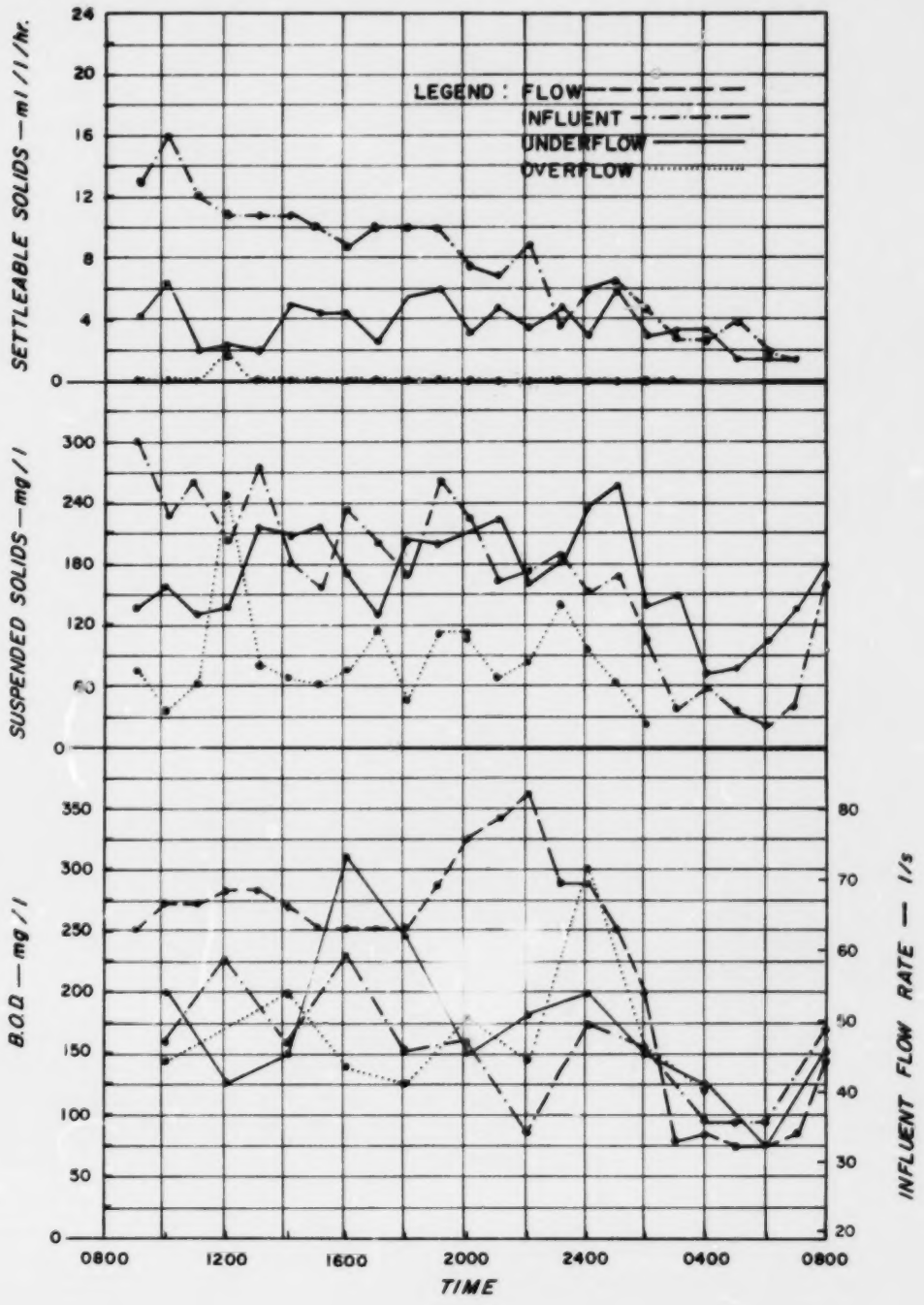


Figure 14 also shows the relationship of the BOD with time at the three sampling points. Due to the volume of analytical equipment required for these tests and the space requirement for the incubation period, we were forced to limit the number of dilutions for each test. For this reason, these results are probably less definitive than those for Settleable and Suspended Solids previously given. Figure 14 does indicate that the BOD concentration in the underflow is not significantly less than in the influent.

Evaluating these results with those just discussed regarding Suspended and Settleable Solids, it is evident that the concentration of soluble and finely suspended organic matter which is measured as BOD must be increasing in the basin at the same time that the larger, heavier solids are accumulating in the basin. The most apparent explanation for this is the anaerobic decomposition of the sludge blanket which had accumulated on the bottom of the basin prior to and during the test. This decomposition breaks down solids and converts them to soluble forms of BOD in the same manner as they are broken down in a digester. Evidence of this is found in the production of gases which caused large amounts of sludge to rise to the surface of the basin and the presence of odors which are associated with the anaerobic decomposition. The mass balances made with the Suspended Solids and BOD data are presented in Tables 5 and 6. They indicate that on the day tested there was not an accumulation of total solids in the basin even though there appears to be a distinct accumulation of large solids as shown in Figure 14, Settleable Solids.

During the course of the first 24-hour testing period, Test 1, the following observations were made of the Pool Sweeps and their performance:

1. All the Pool Sweep units were operating properly at the beginning of the 24-hour testing period.

2. The Sedimentation-Equalization Basin had operated under the test condition for a period in excess of one week prior to the 24-hour test. This was done to insure the stability of the basin operation.

3. As the sweeps passed over the bottom of the basin, they would dislodge large clumps of anaerobic sludge which would rise to the surface where it would stay and accumulate. The rising clumps of sludge would appear adjacent to the floating Pool Sweep head and would be accompanied by released bubbles of gas produced by the anaerobic sludge blanket.

4. The upper sprays on the Pool Sweep floating head which are conventionally used for spraying down the sides of a swimming pool were not effective in breaking up the floating sludge.

Table 5. TEST NO. 1. SUSPENDED SOLIDS MASS BALANCE

| Time | Influent flow rate l/s[a] | Accumulative mass in kilograms[b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & Overflow kg |
| 800 | | | | | |
| 900 | 63.0 | 68.2 | 31.8 | 3.4 | 35.2 |
| 1000 | 66.2 | 122.1 | 71.5 | 6.9 | 78.3 |
| 1100 | 66.2 | 184.6 | 103.4 | 13.0 | 116.4 |
| 1200 | 68.1 | 233.3 | 138.3 | 20.4 | 158.7 |
| 1300 | 68.1 | 298.6 | 189.9 | 29.1 | 218.9 |
| 1400 | 66.2 | 341.5 | 239.0 | 36.0 | 275.1 |
| 1500 | 63.0 | 379.2 | 287.2 | 42.5 | 329.7 |
| 1600 | 63.0 | 432.9 | 326.3 | 48.8 | 375.1 |
| 1700 | 63.0 | 478.3 | 354.9 | 57.1 | 412.0 |
| 1800 | 69.4 | 516.1 | 401.7 | 65.4 | 467.1 |
| 1900 | 75.7 | 582.1 | 450.8 | 74.3 | 525.1 |
| 2000 | 78.9 | 642.6 | 477.5 | 85.2 | 562.7 |
| 2100 | 82.0 | 689.8 | 540.6 | 93.2 | 633.7 |
| 2200 | 69.4 | 741.8 | 587.8 | 103.1 | 690.9 |
| 2300 | 69.4 | 789.8 | 635.3 | 116.9 | 752.2 |
| 2400 | 63.0 | 826.8 | 694.3 | 125.2 | 819.5 |
| 0100 | 44.2 | 865.0 | 753.5 | 128.8 | 882.2 |
| 0200 | 32.8 | 881.5 | 774.8 | 129.3 | 904.1 |
| 0300 | 34.1 | 885.8 | 792.8 | 129.3 | 922.1 |
| 0400 | 34.1 | 893.2 | 801.6 | | 931.0 |
| 0500 | 31.6 | 897.7 | 810.2 | | 939.6 |
| 0600 | 31.6 | 900.4 | 822.3 | | 951.6 |
| 0700 | 33.4 | 905.7 | 838.4 | | 967.8 |
| 0800 | 44.2 | 931.2 | 867.4 | | 996.8 |

[a] 0.063 liters per second (l/s ) = 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

Table 6. TEST NO. 1. BOD MASS BALANCE

| Time | Influent flow rate l/s [a] | Accumulative mass in kilograms [b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & Overflow kg |
| 1000 | 63.0 | 75.0 | 90.9 | 11.9 | 102.8 |
| | 66.2 | | | | |
| 1200 | 66.2 | 182.4 | 150.5 | 45.0 | 195.6 |
| | 68.1 | | | | |
| 1400 | 68.1 | 261.0 | 224.2 | 86.1 | 310.3 |
| | 66.2 | | | | |
| 1600 | 63.0 | 320.2 | 306.0 | 111.5 | 417.5 |
| | 63.0 | | | | |
| 1800 | 63.0 | 433.8 | 408.2 | 129.7 | 537.8 |
| | 63.0 | | | | |
| 2000 | 69.4 | 516.4 | 480.8 | 160.2 | 641.0 |
| | 75.7 | | | | |
| 2200 | 78.9 | 564.7 | 585.9 | 192.2 | 778.2 |
| | 82.0 | | | | |
| 2400 | 69.4 | 652.2 | 688.4 | 227.1 | 915.5 |
| | 69.4 | | | | |
| 0200 | 63.0 | 724.9 | 756.6 | 243.9 | 1000.5 |
| | 44.2 | | | | |
| 0400 | 32.8 | 746.7 | 800.4 | 245.6 | 1046.0 |
| | 34.1 | | | | |
| 0600 | 31.6 | 766.5 | 817.5 | | 1063.1 |
| | 33.4 | | | | |
| 0800 | 44.2 | 807.5 | 854.8 | | 1100.4 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

5. One of the Pool Sweep units repeatedly looped back over its supply hose and became entangled and inoperative. This unit was freed and placed back in service as soon as the problem was observed.

Following Test 1, the Sedimentation-Equalization Basin was drawn down in order to make a visual inspection of the bottom of the basin. There were large deposits of sewage solids on the bottom. It is estimated that there was approximately 20,000 gallons of sludge in the basin. The fluid nature of the deposited sludge made it impossible to determine its spacial arrangement in the basin. There was, however, evidence of Pool Sweep action in a semicircular pattern in front of each Pool Sweep supply line connection point. This pattern was indicative of the lack of mobility previously mentioned which was attributed to the "tethering" of the Pool Sweeps on the supply hose.

The solids which had accumulated on the bottom of the basin could be removed by simply drawing down the basin with the underflow pumps. An investigation of the removal of the solids revealed that it would cost approximately $25 per 1,000 gallons to have the solids trucked away. For the approximate 20,000 gallons estimated to be hauled away, the cost would be approximately $500. It is feasible that this method could be used in the future to handle the accumulated solids in the basin. The operational problems associated with the long detention time of the sludge, namely the production of odors, would exist, however, and would detract from the feasibility of using this as a normal mode of operation.

Following the removal of the deposited sludge, the basin was put back in service with the underflow rate increased to match the average daily influent flow. The higher flow rate was used in an attempt to minimize the deposition of solids until the remaining tests could be run.

A preliminary evaluation of the data was made to identify problems and operational parameters of the Sedimentation-Equalization Basin and the Pool Sweeps. The results of the evaluation were discussed with the Pool Sweep representatives and with the EPA Project Officer. As a result of the preliminary evaluation, it was concluded that the sweep hoses did not have sufficient motion or force to maintain the movement of solids along the bottom of the basin. Since the Pool Sweeps were already operating at the manufacturer's recommended maximum working pressure of 4.22 to 4.92 $kgf/cm^2$ (60-70 psi), this method of producing the increased motion could not be used. The Pool Sweep representatives experimented with a "wye" assembly which allowed a single longer bottom hose to be operated with the combined water of the original two hoses. When operated in a swimming pool, where its performance could be observed, the change in sweep hose configuration showed improved force and mobility according to the manufacturer. The "wye" assembly is shown in Figure 8, in the right forefront.

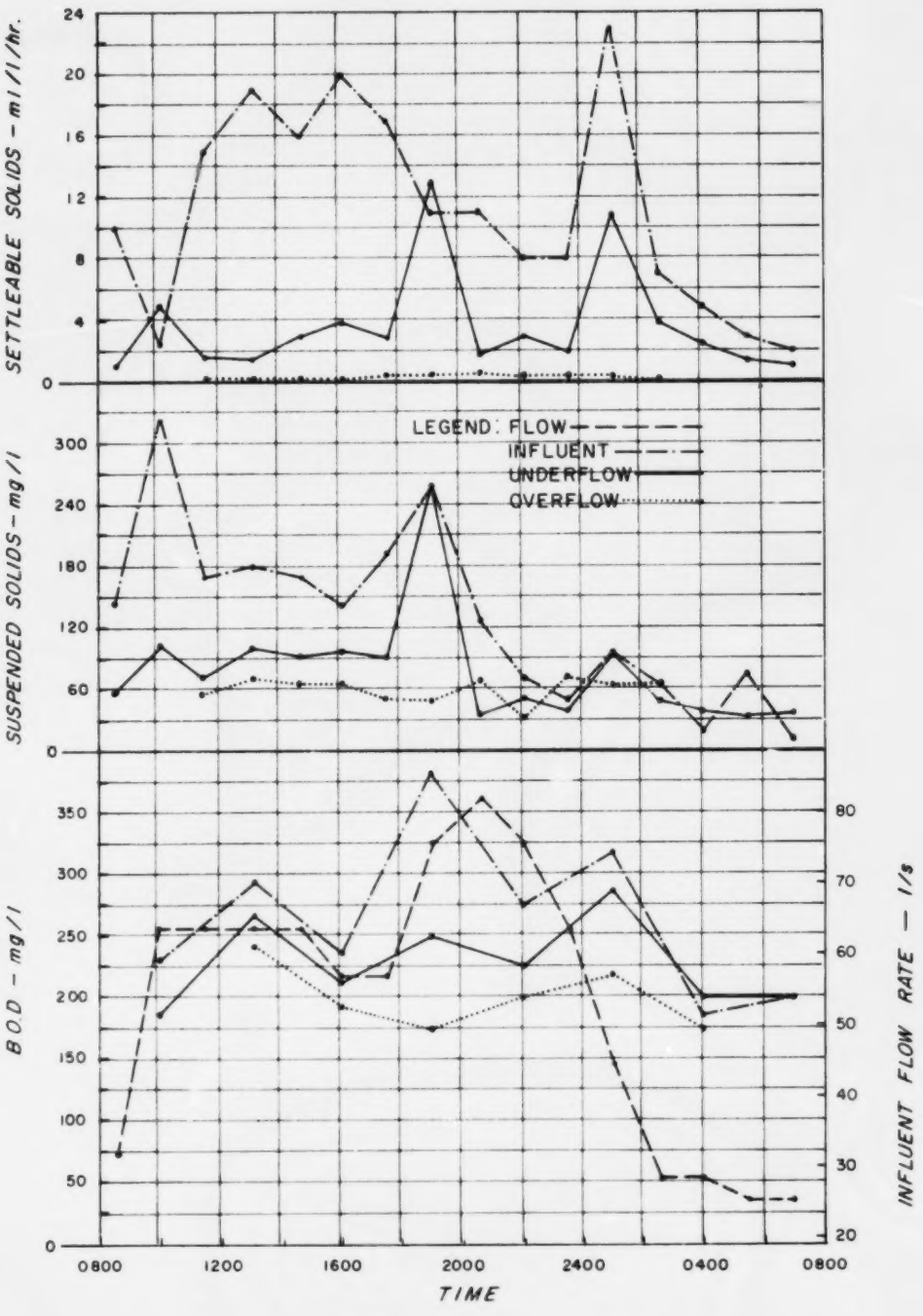
Test No. 2

Test No. 2 was used to study solid flow through the basin and its overall operation. This test was similar to Test No. 1, the only difference being in the amount of time prior to the test at which the pond was operated under the test conditions. That is, with the aerator off, the Pool Sweeps on and the underflow at a continuous rate of approximately 35.0 l/s (0.8 mgd). Seven days prior to Test No. 2, the aerator was turned off and remained off. The Pool Sweeps were operated continuously for seven days prior to the test and during the test. All flows into and out of the Sedimentation-Equalization Basin were monitored every hour and one-half, for a complete 24-hour period. Samples were taken at the basin influent metering channel, clarifier influent channel (basin underflow) and the basin overflow structure. Each sample was analyzed for Settleable Solids, Suspended Solids and BOD. A graphical presentation of the results is shown in Figure 15 which shows that there was a marked decrease in the Settleable Solids concentration between the influent and underflow. It also indicates that a decrease in the Settleable Solids concentration of the influent is not always paralleled by a decrease in the Settleable Solids concentration in the underflow. These results indicate that there is a buildup or a net accumulation of large or heavy Settleable Solids in the basin. It should be noted, however, that the irregular pattern of the concentration of Settleable Solids in the underflow could be an indication that the Pool Sweeps were active and dislodging solids which got into the underflow. The overflow Settleable Solids were quite low throughout the time that the overflow occurred.

Figure 15 shows that the underflow contains less total solids than the influent. Unlike Test No. 1, however, during the low flow period at late night and early morning, the underflow Suspended Solids concentration did not become greater than the influent. This is an indication that during this test there was not a continuing removal of solids from the basin when the influent flow and Suspended Solids concentration dropped off. The overflow Suspended Solids remained considerably lower than the influent or underflow throughout the test.

Figure 15 also shows the relationship of the BOD with time at the three sampling points. The significant things which are shown in this figure is the somewhat parallel strengths of the influent and underflow as measured by the BOD and the fact that the BOD in the underflow is not significantly less than in the influent. This means that if there is an accumulation of the heavier Settleable Solids in the basin, there must also be an increase in the other forms of organic loading, mainly soluble BOD and finer Suspended Solids, that are leaving the basin in the underflow.

Figure 15. Test No. 2 Concentration Curves



The mass balances made with the Suspended Solids and BOD data are presented in Tables 7 and 8. Table 7 indicates that there was a net accumulation of 333 kg (733 lbs) or 50 percent of the total influent Suspended Solids. The BOD mass balance shows that the total BOD leaving the basin, including both the underflow and overflow, was approximately 318 kg (700 lbs) less than the total influent BOD. Of the total leaving the basin, 69% was in the underflow and 31% was in the overflow. The only significant difference between the operation of the Sedimentation-Equalization Basin during Test Nos. 1 and 2 was the amount of time previous to the test that the basin was operated in the mode tested, that is, with the Pool Sweeps on and the aerator off. Under these conditions, it has been shown that there is an accumulation of Settleable Solids in the basin. Prior to Test No. 1, the amount of solids which accumulated in the basin was quite high. In Test No. 2, however, the amount was less because of a much shorter period of accumulation.

Test No. 3

Test No. 3 was performed to evaluate the effectiveness of the Pool Sweeps, specifically. For this test, the aerator was turned off six days prior to the test. The Pool Sweeps were turned off six days prior to the test and remained off throughout the test. The underflow pumps ran continuously at a rate of approximately 35.0 l/s (0.8 mgd) throughout the test. The sampling points and the analyses made of the samples were the same as those used for Test Nos. 1 and 2. A summary of the significant results of this test are shown graphically in Figure 16 and in tabular form in Tables 9 and 10.

Figure 16 clearly shows that there was a marked decrease in the amount of Settleable Solids which were being removed from the basin in the underflow when the Pool Sweeps were turned off. As before, the overflow Settleable Solids remained quite low throughout the test. The curves showing the variation in Suspended Solids with time indicates that when the Pool Sweeps were not operating, the Suspended Solids concentrations in the underflow remained fairly constant at approximately 40 to 80 milligrams per liter (mg/l) with the exception of the first data point at 0830. The uniformity or variability of these Suspended Solids concentrations in the underflow is felt to be a direct indication of the influence of the Pool Sweeps.

The curves showing the BOD concentration with time generally show that the underflow and overflow concentration remained similar throughout the period when overflow occurred. The significance of this, when compared to the same evaluation made during Test Nos. 1 and 2 indicates that when the Pool Sweeps are not operating, the consistency of the underflow represents that of a fairly homogenous mixture of wastewater in the basin. It could be reasoned, therefore, that the Pool Sweeps, as shown in Test Nos. 1 and 2, were changing the BOD concentration in the underflow as a result of their operation and that the lack of variability of underflow BOD concentration is a direct result of the lack of Pool Sweep operation.

Table 7. TEST NO. 2. SUSPENDED SOLIDS MASS BALANCE

| Time | Influent flow rate l/s[a] | Accumulative mass in kilograms[b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & overflow kg |
| 0830 | 31.6 | 24.8 | 10.8 | | 10.8 |
| 1000 | 63.1 | 135.3 | 30.1 | | 30.1 |
| 1130 | 63.1 | 193.4 | 43.9 | 8.7 | 52.6 |
| 1300 | 63.1 | 254.6 | 62.5 | 19.6 | 82.1 |
| 1430 | 63.1 | 312.9 | 79.6 | 30.0 | 109.6 |
| 1600 | 56.8 | 357.6 | 97.5 | 38.1 | 135.6 |
| 1730 | 56.8 | 416.6 | 114.5 | 44.4 | 158.9 |
| 1900 | 75.7 | 523.3 | 163.9 | 55.7 | 219.6 |
| 2030 | 82.0 | 579.5 | 170.8 | 73.3 | 244.2 |
| 2200 | 75.7 | 608.7 | 180.8 | 80.5 | 261.2 |
| 2330 | 63.1 | 626.4 | 188.9 | 92.0 | 280.9 |
| 0100 | 44.2 | 649.8 | 206.1 | 95.3 | 301.5 |
| 0230 | 28.4 | 659.8 | 215.8 | 96.4 | 312.2 |
| 0400 | 28.4 | 663.0 | 223.2 | | 319.6 |
| 0530 | 25.2 | 673.5 | 229.2 | | 325.6 |
| 0700 | 25.2 | 675.1 | 236.5 | | 332.9 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

Table 8. TEST NO. 2. BOD MASS BALANCE

| Time | Influent flow rate l/s[a] | Accumulative mass in kilograms[b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & Overflow kg |
| 0830 | 31.6 | | | | |
| 1000 | 63.1 | 156.6 | 69.3 | | 69.3 |
| 1130 | 63.1 | | | | |
| 1300 | 63.1 | 357.5 | 168.5 | 73.5 | 242.1 |
| 1430 | 63.1 | | | | |
| 1600 | 56.8 | 501.6 | 249.1 | 118.9 | 367.9 |
| 1730 | 56.8 | | | | |
| 1900 | 75.7 | 812.6 | 342.7 | 196.3 | 539.0 |
| 2030 | 82.0 | | | | |
| 2200 | 75.7 | 1032.8 | 427.0 | 284.8 | 711.8 |
| 2330 | 63.1 | | | | |
| 0100 | 44.2 | 1189.8 | 531.9 | 307.3 | 839.1 |
| 0230 | 28.4 | | | | |
| 0400 | 28.4 | 1246.5 | 606.8 | 310.3 | 917.0 |
| 0530 | 25.2 | | | | |
| 0700 | 25.2 | 1301.0 | 681.7 | | 991.9 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

Figure 16. Test No. 3 Concentration Curves

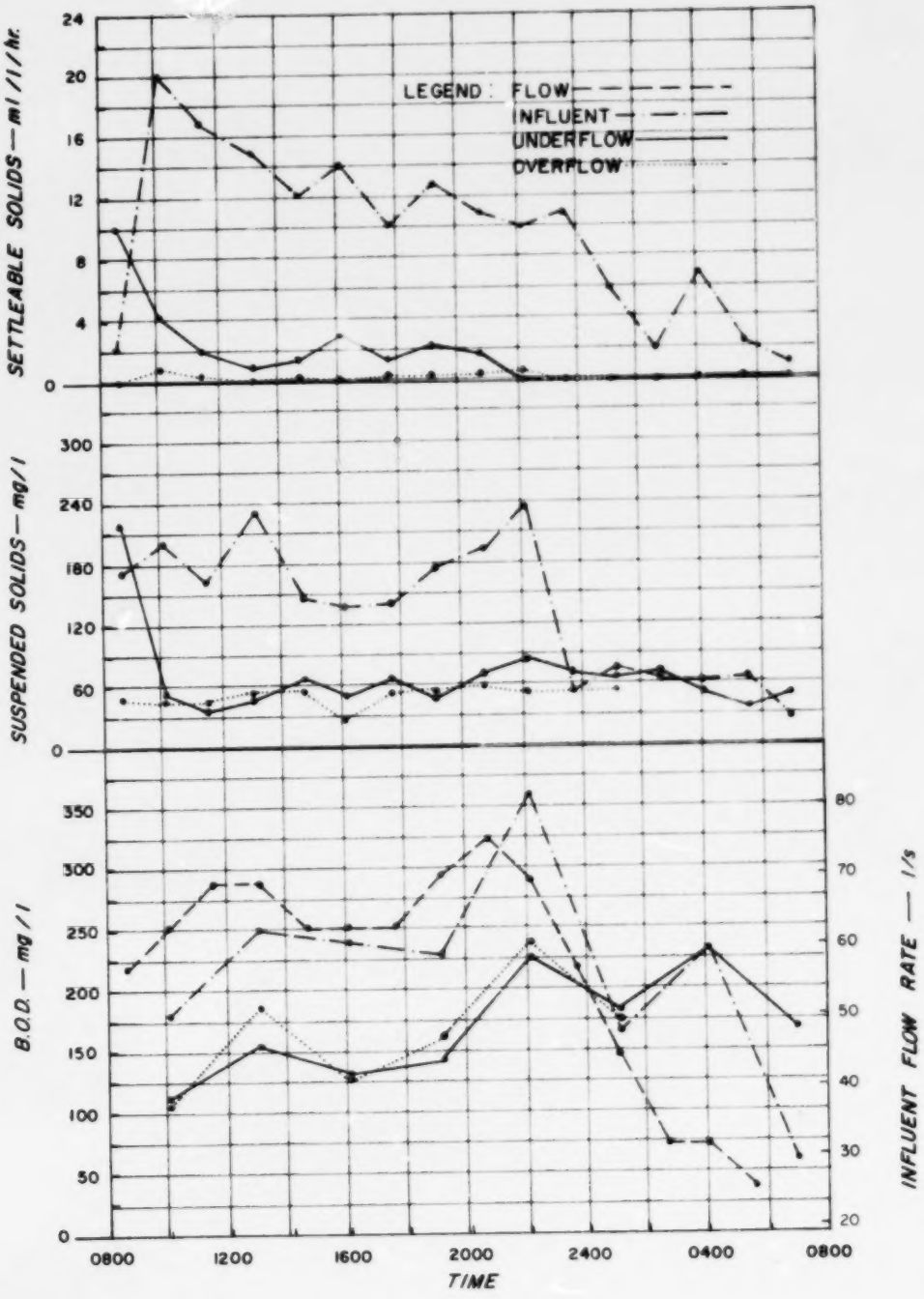


Table 9. TEST NO. 3. SUSPENDED SOLIDS MASS BALANCE

| Time | Influent flow rate l/s[a] | Accumulative mass in kilograms[b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & overflow kg |
| 0830 | 56.8 | 23.0 | 40.6 | 6.0 | 46.6 |
| 1000 | 62.1 | 92.1 | 50.6 | 13.5 | 64.1 |
| 1130 | 69.4 | 152.4 | 58.5 | 22.0 | 80.5 |
| 1300 | 69.4 | 238.8 | 68.1 | 31.7 | 99.8 |
| 1430 | 63.1 | 289.5 | 81.0 | 40.3 | 121.3 |
| 1600 | 63.1 | 336.8 | 90.3 | 44.8 | 135.1 |
| 1730 | 63.1 | 385.5 | 102.3 | 53.0 | 155.4 |
| 1900 | 69.4 | 452.2 | 110.0 | 62.4 | 172.4 |
| 2030 | 75.7 | 444.9 | 123.6 | 76.0 | 199.6 |
| 2200 | 69.4 | 644.8 | 140.3 | 86.4 | 226.6 |
| 2330 | 56.8 | 662.7 | 153.7 | 92.9 | 246.6 |
| 0100 | 44.2 | 681.0 | 166.6 | 95.9 | 262.4 |
| 0230 | 31.6 | 692.0 | 179.7 | | 275.6 |
| 0400 | 31.6 | 702.7 | 189.4 | | 285.3 |
| 0530 | 25.2 | 712.0 | 197.1 | | 293.0 |
| 0700 | 25.2 | 716.0 | 206.8 | | 302.7 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

Table 10. TEST NO. 3. BOD MASS BALANCE

| Time | Influent flow rate l/s[a] | Accumulative mass in kilograms[b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & Overflow kg |
| 0830 | 56.8 | | | | |
| 1000 | 63.1 | 122.6 | 41.2 | 32.2 | 73.4 |
| 1130 | 69.4 | | | | |
| 1300 | 69.4 | 309.8 | 99.3 | 101.5 | 200.8 |
| 1430 | 63.1 | | | | |
| 1600 | 63.1 | 473.3 | 148.0 | 139.8 | 287.8 |
| 1730 | 63.1 | | | | |
| 1900 | 69.4 | 645.6 | 202.3 | 199.7 | 402.0 |
| 2030 | 75.7 | | | | |
| 2200 | 69.4 | 915.3 | 286.6 | 289.6 | 576.2 |
| 2330 | 56.8 | | | | |
| 0100 | 44.2 | 993.9 | 354.0 | 307.5 | 661.5 |
| 0230 | 31.6 | | | | |
| 0400 | 31.6 | 1072.3 | 440.2 | | 747.6 |
| 0530 | 25.2 | | | | |
| 0700 | 25.2 | 1088.6 | 503.8 | | 811.3 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

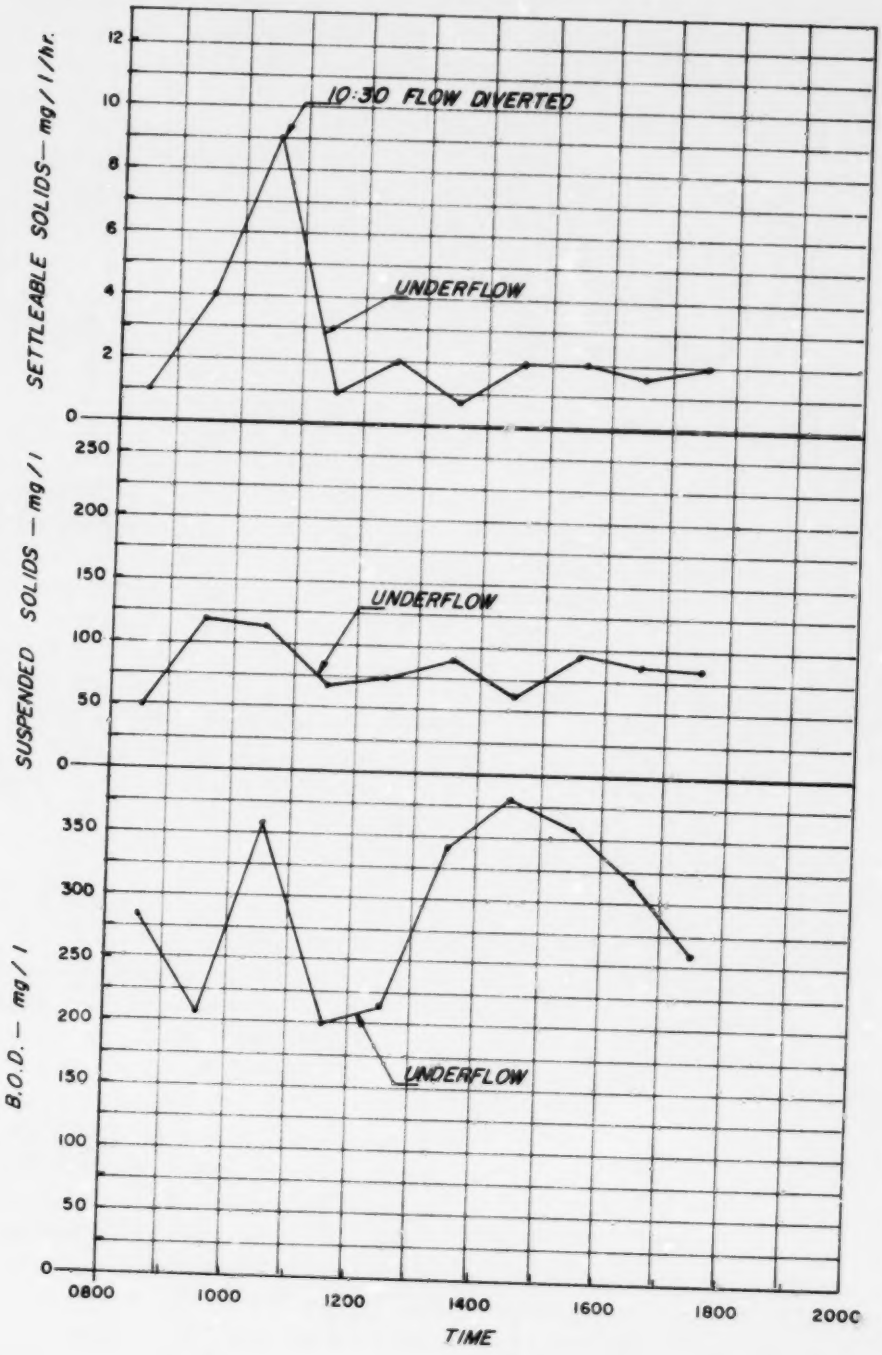
The mass balances for Suspended Solids and BOD through the Sedimentation-Equalization Basin are presented in Tables 9 and 10. Comparing the Suspended Solids mass balance from this test with that of Test No. 2 indicates that without the Pool Sweeps in operation there was only a slight decrease in the amount of Suspended Solids removed in the underflow. This result indicates that while the Pool Sweeps did have a positive effect on the removal of Suspended Solids, the net effect was not as substantial as had been anticipated. The BOD mass balance, shown in Table 10, shows that 46% of the influent BOD was removed in the underflow. This compares to a 60% removal obtained in Test No. 2 when the Pool Sweeps were in operation. This again documents the fact that although there was an increase in the amount of BOD being removed in the underflow with the Pool Sweeps in operation, that increase was not substantial.

Test No. 4

To investigate the effects of the influent configuration of the Sedimentation-Equalization Basin as it applies to the solids flow characteristics of the basin, Test No. 4 was devised. For this test, the aerator was turned off five days prior to and during the test. The Pool Sweeps ran continuously for five days prior to and during the test. The underflow pumps ran continously at an average rate of 32.8 l/s (0.75 mgd) throughout the test. On the day of the test, as soon as the Sedimentation-Equalization Basin began to overflow, the influent was diverted around the basin directly to the primary clarifier. After the diversion had been made, the only things operating within the basin were the underflow pump and the Pool Sweeps. The objective of this test was to determine if the influent configuration, as previously shown in Figure 4, had a discernible effect on the ability of the Pool Sweeps or the bottom currents produced by the underflow to aid in the removal of Settleable Solids and Suspended Solids and BOD from the basin.

When the test began and the influent was diverted, the influent BOD and Suspended and Settleable Solids obviously stopped also. The measurements of the underflow concentration from that point on were measurements of the basin contents and any contribution of solids which were dislodged from the bottom by either the Pool Sweeps or the underflow current. Comparing the results shown in Figure 17 for Test No. 4 and Figure 15 for Test No. 2, it is obvious that a major portion of the solids in the underflow come directly from the influent flow. Figure 17 clearly shows that when the influent flow was diverted, the underflow Settleable Solids dropped immediately to the level associated with the minimum flows at night during Test No. 2. The Settleable Solids tests indicated that the influent configuration and any resulting flow circulation patterns did not have a significant effect on the concentration of Settleable Solids in the underflow. Comparing Suspended Solids concentration curves also indicates that any turbulence or circulation patterns in the area of the center sump caused by the incoming flow

Figure 17. Test No. 4 Concentration Curves



did not significantly affect the concentration of Suspended Solids removed in the underflow. The fact that the Settleable Solids, Suspended Solids and BOD remained fairly stable and similar to those values experienced in Test No. 2 is due to the fact that without the influent waste we are drawing off the fairly homogeneous basin contents which have a relatively high strength due to the accumulation of solids in the basin.

Table 11 indicates the accumulative total pounds of both BOD and Suspended Solids in the underflow during the testing period. During the time from 10:00 a.m. until 7:00 p.m., 247 kg (545 lbs) of BOD and 67 kg (148 lbs) of Suspended Solids were contained in the underflow. During the same period of time in Test No. 2, where the only significant difference was the presence of the influent flow to the basin, 211 kg (465 lbs) of BOD and 79 kg (174 lbs) of Suspended Solids were contained in the underflow. In general, the mass balance information indicates that the configuration of the basin center sump and the physical arrangement of the influent pipe only slightly affected the overall Suspended Solid and BOD removal in the basin.

Table 11. TEST NO. 4. UNDERFLOW MASS

| Time | Underflow rate l/s[a] | Accumulative mass in kilograms[b] | |
|---|---|---|---|
| | | Suspended solids kg | BOD kg |
| 0830 | 136.1 | 6.4 | 36.2 |
| 0930 | 136.1 | 21.9 | 63.4 |
| 1030 | 133.7 | 36.4 | 109.1 |
| 1130 | 132.5 | 44.8 | 134.2 |
| 1230 | 128.9 | 53.9 | 160.7 |
| 1330 | 127.7 | 64.8 | 202.0 |
| 1430 | 119.4 | 71.5 | 245.1 |
| 1530 | 101.5 | 80.6 | 279.8 |
| 1630 | 101.5 | 89.3 | 310.7 |
| 1730 | 101.5 | 97.8 | 335.8 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

## STORM FLOW TESTING

Tests Nos. 5 through 9 were conducted in the winter of 1972-1973 and were tests of the hydraulic surge facility under wet weather flow conditions. All of the tests, with the exception of No. 6, were carried out with the aerator off, the Pool Sweeps on and a constant underflow rate. Figure 18 graphically shows the daily rainfall for the winter of 1971-1972 and 1972-1973 and the resuling average daily flow into the demonstration facilities. It should be noted that the winter of 1971-1972 was very dry with only thirteen total inches of rainfall compared to a normal of about thirty inches. Because of the lack of any significant storm flows into the demonstration facilities, we were not able to generate any meaningful data on the performance of the surge facility under stormflow conditions during the 1971-72 winter. For this reason, the Demonstration Project was extended to include the winter of 1972-73. The days on which the major tests were made are shown in Figure 18. The major storms in January, 1973, were not tested because of equipment failure affecting the Pool Sweep operation.

### Test No. 5

The test conditions for Test No. 5 were moderate stormflows and normal Sedimentation-Equalization Basin operation. The influent flow for this test ranged from 75.7 l/s (1,200 gpm) to 126 l/s (2,000 gpm). The underflow rate was a constant 37.8 l/s (600 gpm). For this test, the aerator was turned off and the Pool Sweeps were turned on at 8:00 a.m. in the morning just prior to the beginning of the test. A graphical presentation of the test results for Settleable Solids, Suspended Solids, and BOD concentrations are shown in Figure 19. Comparing the Settleable Solids curves and the Suspended Solids curves, it can be seen that most of the larger heavier Settleable Solids were accumulating in the basin rather than being carried out with the underflow. And at the same time, the remaining Suspended Solids were being removed in the underflow almost as fast as they were coming into the basin. The curve showing the BOD concentration versus time indicates that the underflow BOD remained above the influent BOD concentration during most of the testing period. This would indicate that during the higher stormflow periods, there is a flushing out of the higher concentrations of BOD in the basin by the less concentrated stormflows. Observation of the overflow quality characteristics of the surge facility indicates that almost all Settleable Solids were removed before overflow, that a significant amount (34%) of the Suspended Solids were removed before overflow and that a large amount (79%) of BOD was removed before overflow.

To more precisely document the total flow of BOD and Suspended Solids through the basin, mass balances shown in Tables 12 and 13 were prepared. The Suspended Solids mass balance shown in Table 12 indicates that 33% of the influent Suspended Solids was removed in the underflow. The overflow contained

Figure 18. Rainfall and Daily Flows

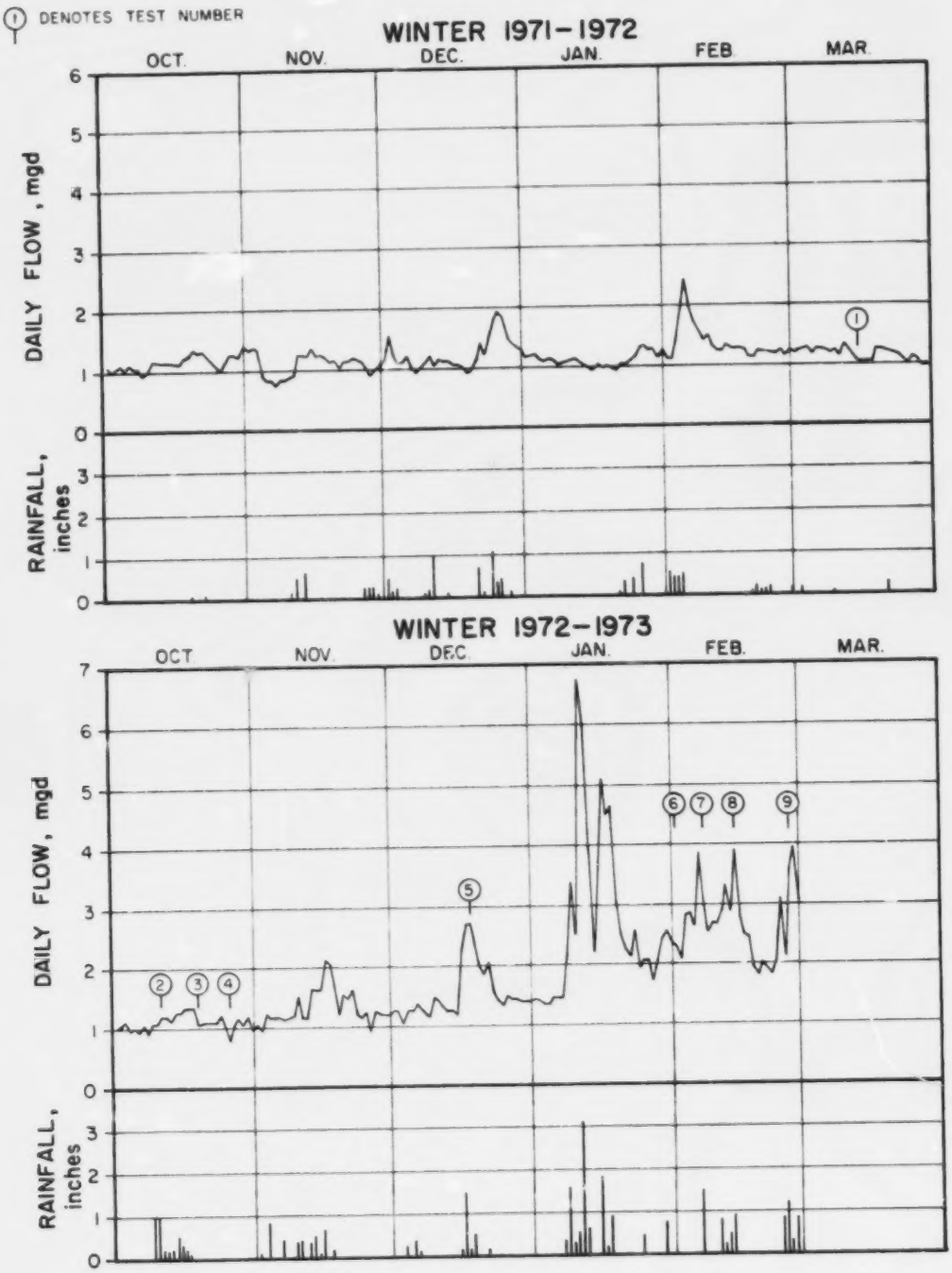


Figure 19. Test No. 5 Concentration Curves

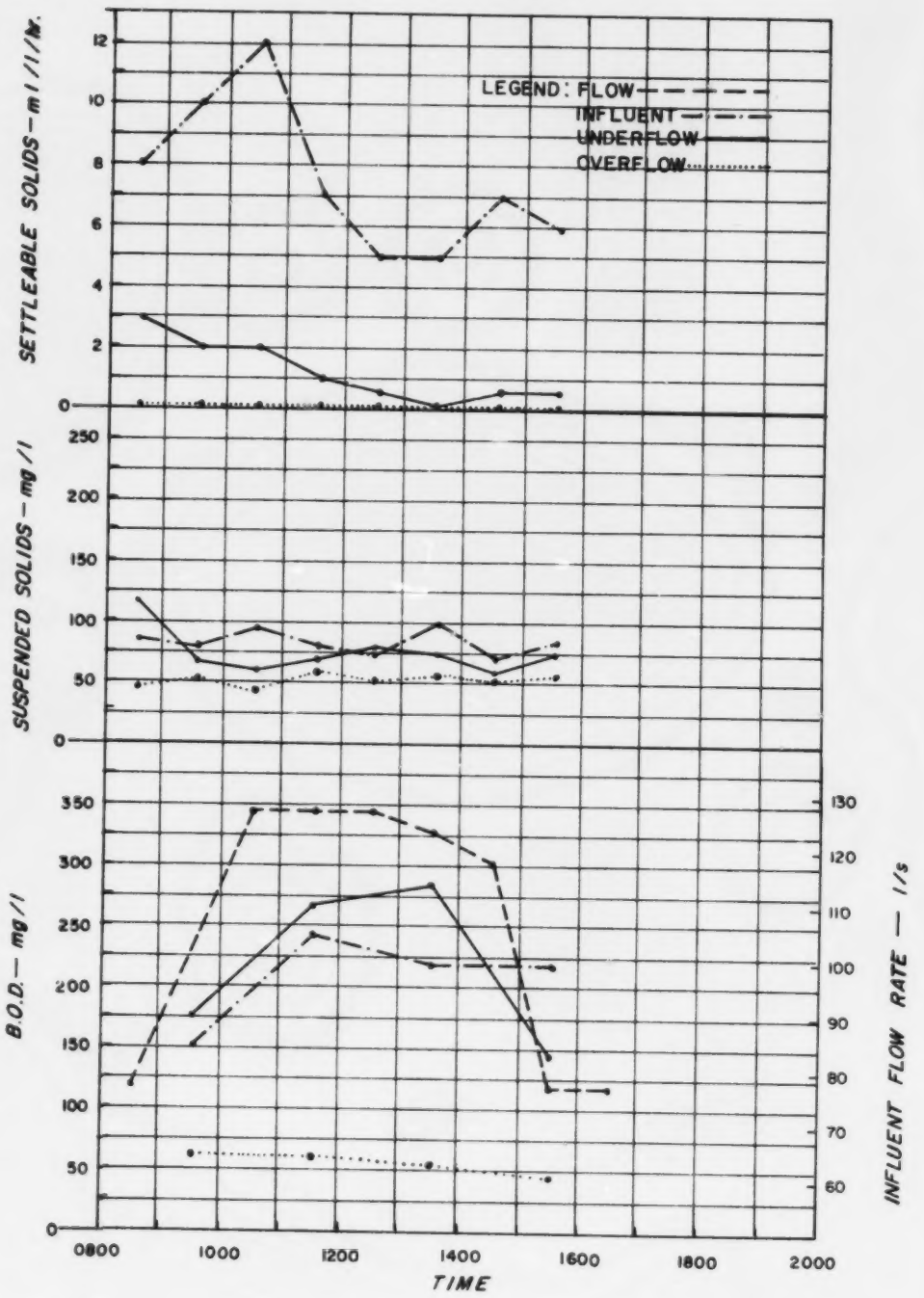


Table 12. TEST NO. 5. SUSPENDED SOLIDS MASS BALANCE

| Time | Influent flow rate l/s[a] | Accumulative mass in kilograms[b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & overflow kg |
| 0830 | 75.7 | 22.6 | 15.5 | 6.5 | 22.0 |
| 0930 | 82.0 | 45.0 | 24.4 | 15.1 | 39.5 |
| 1030 | 126.2 | 85.9 | 32.7 | 28.9 | 62.5 |
| 1130 | 126.2 | 121.8 | 42.3 | 49.0 | 91.3 |
| 1230 | 126.2 | 156.3 | 52.9 | 65.6 | 118.5 |
| 1330 | 123.0 | 201.4 | 62.2 | 83.5 | 145.7 |
| 1430 | 116.7 | 231.7 | 70.7 | 98.7 | 169.4 |
| 1530 | 75.7 | 253.5 | 80.9 | 106.9 | 187.8 |
| 1630 | 75.7 | 275.3 | 90.0 | 113.9 | 203.7 |

[a]0.063 liters per second (l/s) = 1 gallon per minute (gpm)
[b]0.454 kilograms (kg) = 1 pound (lb)

Table 13. TEST NO. 5. BOD MASS BALANCE

| Time | Influent flow rate l/s[a] | Accumulative mass in kilograms[b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & overflow kg |
| 0830 | 75.7 | | | | |
| 0930 | 82.0 | 102.2 | 46.8 | 25.0 | 71.8 |
| 1030 | 126.2 | | | | |
| 1130 | 126.2 | 320.1 | 118.9 | 63.6 | 182.5 |
| 1230 | 126.2 | | | | |
| 1330 | 123.0 | 513.0 | 193.8 | 96.7 | 290.6 |
| 1430 | 116.7 | | | | |
| 1530 | 75.7 | 654.7 | 231.5 | 114.0 | 345.5 |
| 1630 | 75.7 | | | | |

[a]0.063 liters per second (l/s) = 1 gallon per minute (gpm)
[b]0.454 kilograms (kg) = 1 pound (lb)

approximately 41% of the mass of Suspended Solids due to the high overflow rate even though the concentration remained below that of the influent and underflow. This left approximately 26% of the influent Suspended Solids which accumulated in the basin. The BOD mass balance shown in Table 13 indicates that approximately 35% of the influent BOD was removed in the underflow while only 17% remained in the overflow. This left approximately 48% which accumulated in the basin during the testing period.

Test No. 6

Test No. 6 was conducted to duplicate the operational parameters of Test No. 4, that is, try and determine if the basin influent configuration could be influencing the flow of solids through the basin. For this test, the aerator was turned off two days prior to the beginning of the test. The Pool Sweeps ran continuously for two days prior to the test and during the test. The underflow rate varied from 39.4 l/s (625 gpm) at the beginning of the test to 30.6 l/s (485 gpm) at the end of the test. The influent flow was diverted around the surge facility to the clarifier just prior to the beginning of the testing period. The underflow test results are shown in Figure 20. In general, the strength of the underflow, as measured by the Settleable Solids, Suspended Solids and BOD, was less during this test than it was for Test No. 4. Settleable Solids, Suspended Solids, and BOD were approximately 1.5 ml/l/hr., 80 mg/l and 300 mg/l, respectively, during Test No. 4 compared to 0.2 ml/l/hr., 50 mg/l and 90 mg/l, respectively, during Test No. 6. This was due to the fact that this test was conducted during the winter when the overall flow through the basin was greater than during the previous testing period. The average influent concentrations for both tests which should be used when comparing the underflow concentrations were previously shown in Table 1. The consistent low values and lack of variation shown in Figure 20 again indicates that the action of the Pool Sweeps was not dislodging or moving solids so that they could be removed in the underflow. Table 14 shows the accumulative total pounds of Suspended Solids and BOD which were removed in the underflow. The decrease in the total kilograms of BOD in the underflow for this test as compared to Test No. 4 is due primarily to the weaker waste as mentioned in the discussion of Test No. 5.

Test Nos. 7, 8 and 9

Tests 7, 8 and 9 conducted in the month of February, 1973, were the principal tests of the storm flow operation of the Sedimentation-Equalization Basin. For each of these tests, the aerator was turned off and the Pool Sweeps turned on in the morning prior to the beginning of the tests. The underflow rate remained at approximately 37.8 l/s (600 gpm) during each of the three tests. In Test No. 7, the influent flow rate varied between 118.2 l/s (1,874 gpm) and 170.3 l/s (2,706 gpm). This represents a detention time in the Sedimentation-

Figure 20. Test No. 6 Concentration Curves

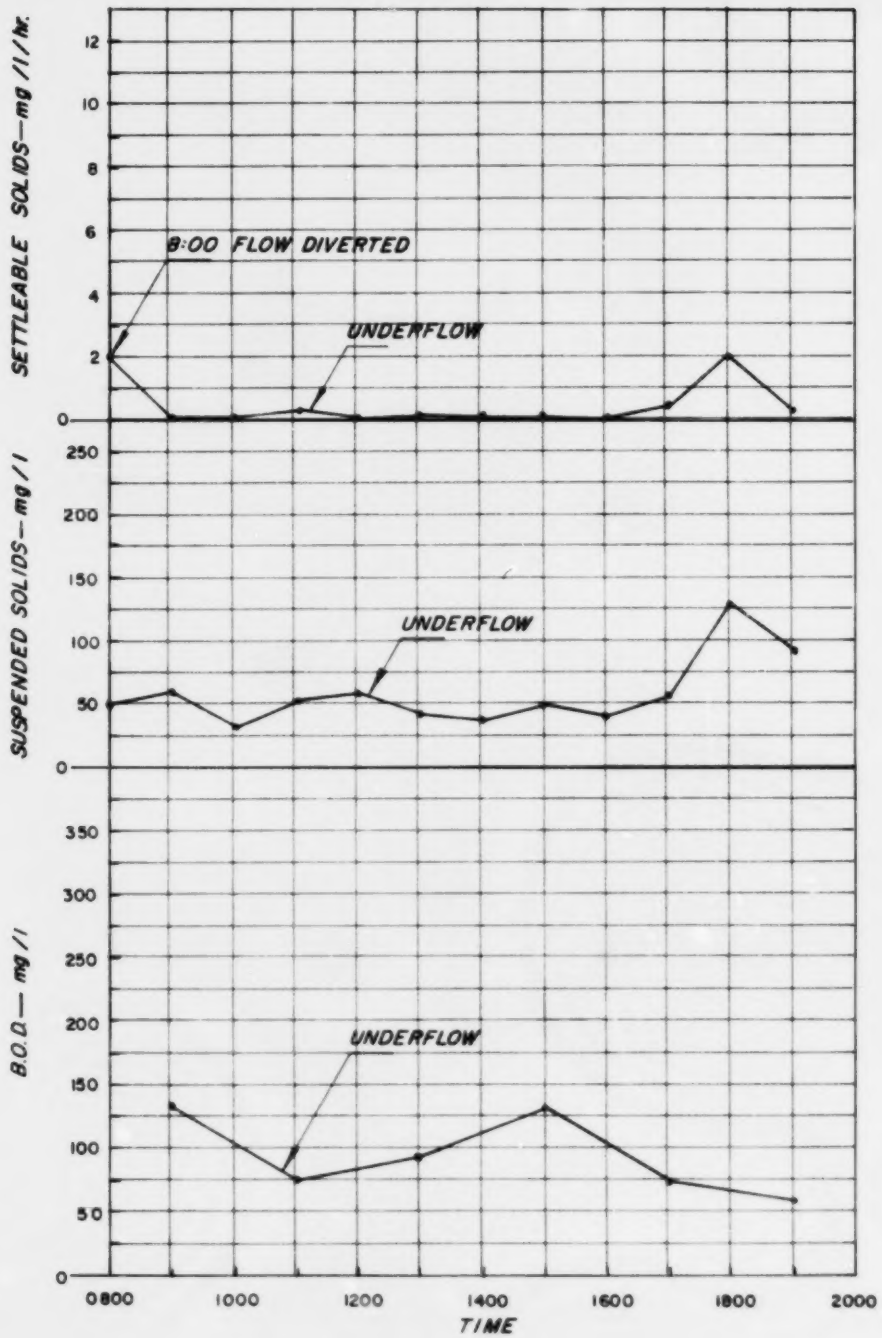


Table 14. TEST NO. 6. UNDERFLOW MASS

| Time | Underflow rate l/s[a] | Accumulative mass in kilograms[b] | |
|---|---|---|---|
| | | Suspended solids kg | BOD kg |
| 0800 | 149.2 | 7.2 | |
| 0900 | 149.2 | 15.8 | 36.9 |
| 1000 | 149.2 | 20.1 | |
| 1100 | 146.9 | 28.2 | 57.6 |
| 1200 | 140.9 | 36.2 | |
| 1300 | 140.9 | 41.4 | 81.3 |
| 1400 | 132.5 | 46.1 | |
| 1500 | 132.5 | 52.3 | 113.9 |
| 1600 | 131.3 | 57.5 | |
| 1700 | 125.3 | 64.4 | 131.8 |
| 1800 | 119.4 | 79.1 | |
| 1900 | 115.8 | 89.4 | 145.0 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

Equalization Basin of approximately 4-1/2 to 5-1/2 hours. In both Test Nos. 8 and 9, the influent flow rate varied between approximately 183.9 l/s (2,915 gpm) and 240.8 l/s (3,817 gpm). This represents a detention time in the Sedimentation-Equalization Basin of between 3-1/2 and 4-1/2 hours. The flows during Test Nos. 8 and 9 were very close to the design peak flow for the surge facility of 263 l/s (6 mgd) and the design detention time of three hours. A graphical presentation of the storm flow testing data is given in Figures 21, 22, and 23. In addition, the data are tabulated in terms of the mass balances for both Suspended Solids and BOD in Tables 15 through 19.

Comparing the Settleable Solids curves for each of the tests, it can be seen that when the storm flows became a very large percentage of the total flow, the Settleable Solids became less concentrated and less variable, primarily between three and five milliliters per liter per hour (ml/l/hr). The higher storm flows did not significantly increase the concentration of Settleable Solids in the overflow over the values occurring during earlier tests with much lower overflow rates. Even when the detention time in the Sedimentation-Equalization Basin was reduced to less than four hours there was an accumulation of larger and/or heavier solids in the basin. This is apparent when the Settleable Solids concentrations for the influent and underflow are compared.

The overflow Suspended Solids concentrations increased only marginally over what they were in earlier tests. As in previous tests with lower influent flow rates, the underflow Suspended Solids concentration is about the same as or slightly less than the influent concentration.

The Suspended Solids mass balances through the Sedimentation-Equalization Basin for the three major storm flow tests indicate that when the storm flow rate became quite high, near 241 l/s (3,816 gpm), the percentage of influent Suspended Solids being removed in the underflow was reduced. However, the total amount of Suspended Solids being removed from the basin including the overflow was approximately the same for all three tests. In the three tests, the percentage of Suspended Solids which was not removed and, therefore, must have accumulated in the basin during the seven-hour period from 10:00 a.m. to 5:00 p.m., amounted to 43%, 42% and 38% for Test Nos. 7, 8 and 9, respectively.

In the case of the BOD mass balance through the Sedimentation-Equalization Basin, there was a marked difference in the manner in which the mass passed through the basin. Comparing Test Nos. 7 and 9, when the influent flow rate varied from 171 l/s (2,706 gpm) to 241 l/s (3,817 gpm), respectively, the percentage of the influent BOD being removed in the underflow was fairly constant at about 15%. The percentage of influent BOD removed in the overflow, however, varied considerably from 44% in Test No. 7 to 76% in Test No. 9.

Figure 21. Test No. 7 Concentration Curves

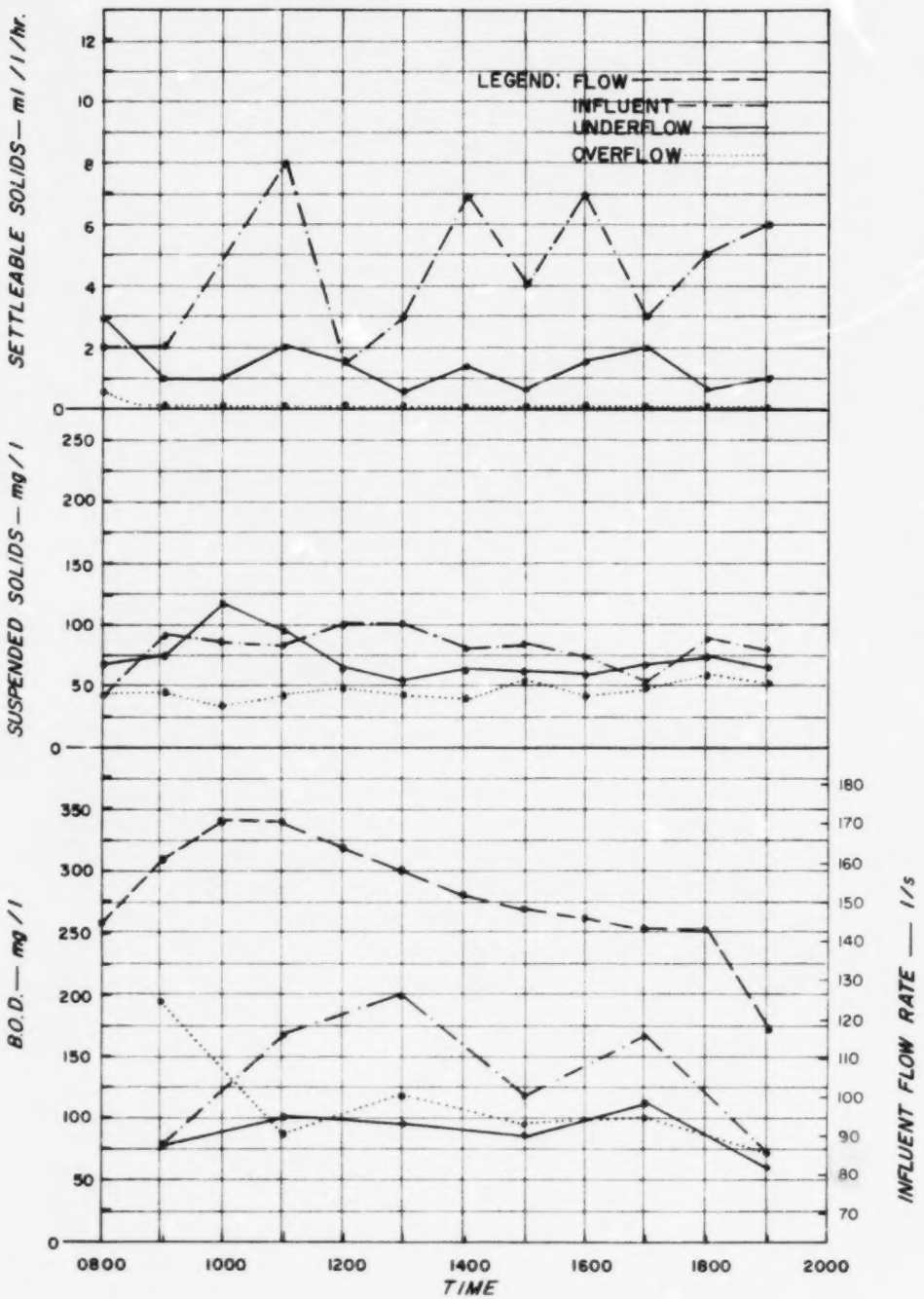


Figure 22. Test No. 8 Concentration Curves

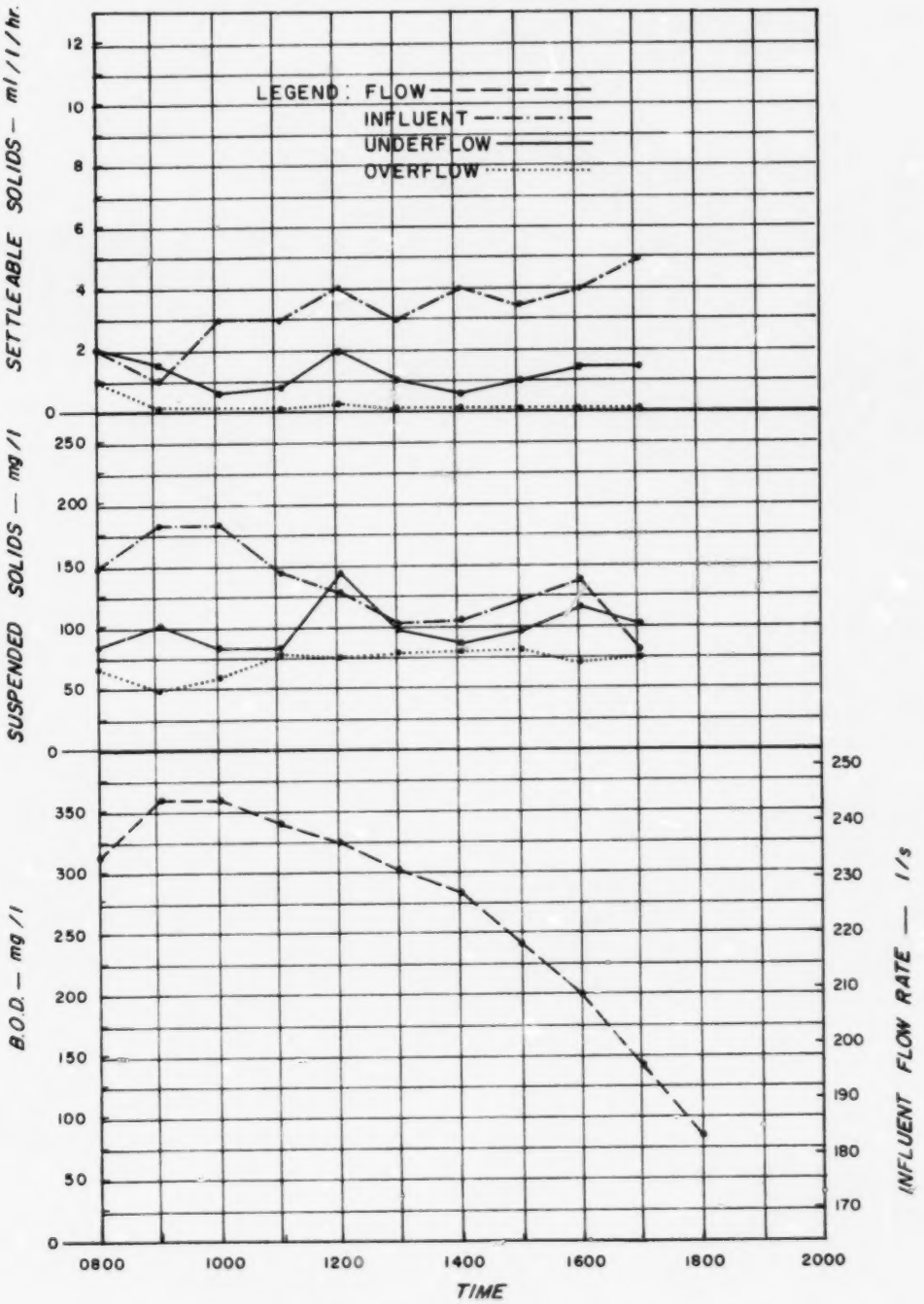


Figure 23. Test No. 9 Concentration Curves

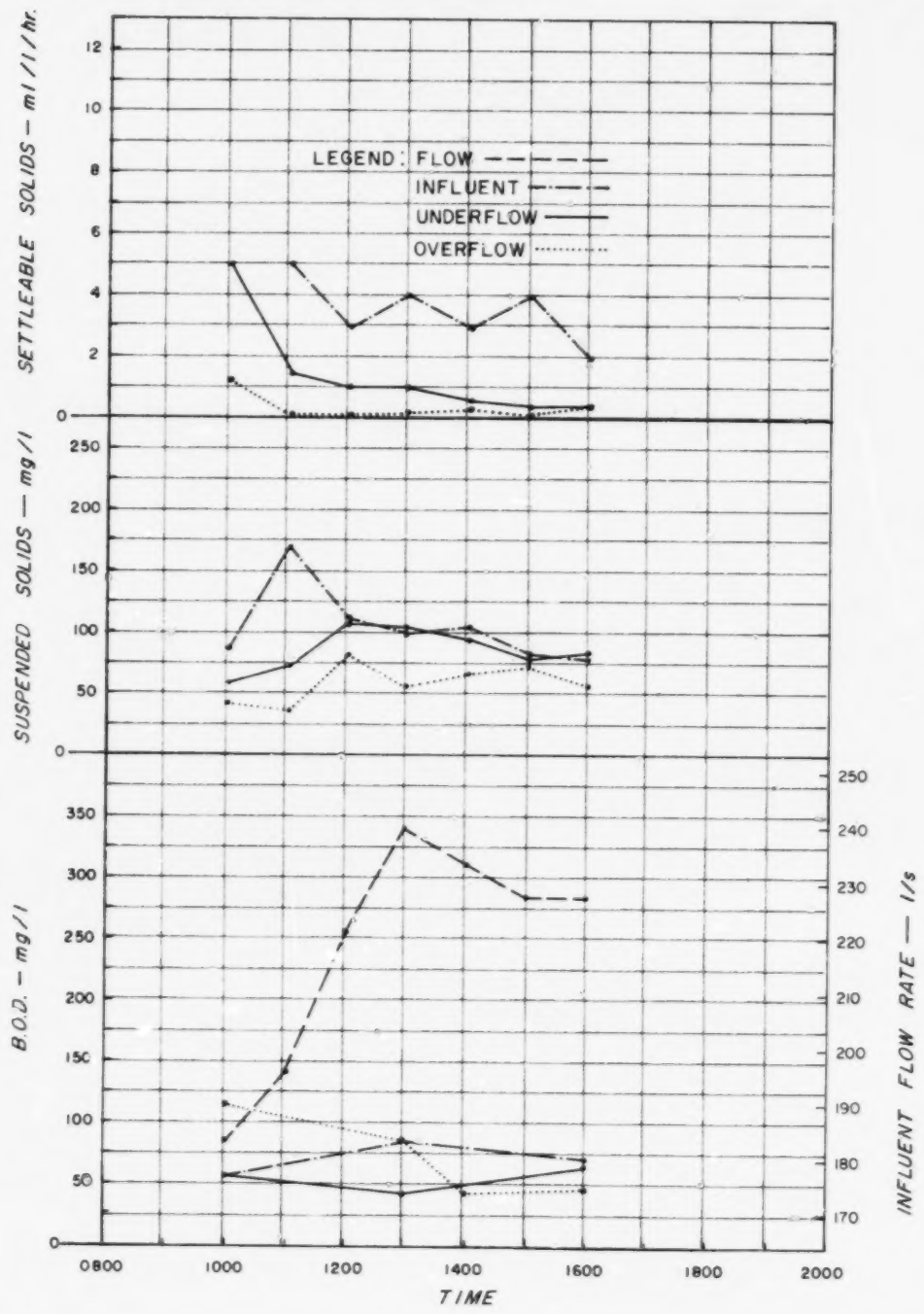


Table 15. TEST NO. 7. SUSPENDED SOLIDS MASS BALANCE

| Time | Influent flow rate l/s[a] | Accumulative mass in kilograms[b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & overflow kg |
| 0800 | 145.1 | 21.4 | 9.7 | 15.4 | 25.1 |
| 0900 | 160.9 | 75.8 | 19.9 | 35.8 | 55.7 |
| 1000 | 170.3 | 128.5 | 36.5 | 52.9 | 89.4 |
| 1100 | 170.3 | 178.8 | 49.2 | 72.0 | 121.2 |
| 1200 | 164.0 | 237.8 | 58.3 | 93.8 | 152.1 |
| 1300 | 157.7 | 294.0 | 66.1 | 111.9 | 178.0 |
| 1400 | 151.4 | 337.6 | 74.9 | 127.4 | 202.3 |
| 1500 | 148.3 | 381.4 | 82.9 | 148.9 | 231.8 |
| 1600 | 145.1 | 417.9 | 90.3 | 162.8 | 253.1 |
| 1700 | 141.9 | 441.4 | 99.8 | 177.4 | 277.2 |
| 1800 | 141.9 | 486.9 | 109.5 | 198.4 | 307.9 |
| 1900 | 116.7 | 520.4 | 117.8 | 211.7 | 329.5 |

[a] 0.063 liters per second (l/s) - 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

Table 16. TEST NO. 7. BOD MASS BALANCE

| Time | Influent flow rate l/s[a] | Accumulative mass in kilograms[b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & overflow, kg |
| 0800 | 145.1 | | | | |
| 0900 | 160.9 | 91.4 | 21.4 | 167.1 | 188.5 |
| 1000 | 170.3 | | | | |
| 1100 | 170.3 | 297.3 | 50.0 | 241.1 | 291.1 |
| 1200 | 164.0 | | | | |
| 1300 | 157.7 | 524.3 | 77.2 | 343.0 | 420.1 |
| 1400 | 151.4 | | | | |
| 1500 | 148.3 | 647.0 | 101.5 | 413.2 | 514.7 |
| 1600 | 145.1 | | | | |
| 1700 | 141.9 | 821.9 | 133.0 | 487.6 | 620.5 |
| 1800 | 141.9 | | | | |
| 1900 | 116.7 | 880.7 | 151.6 | 526.3 | 678.0 |

[a] 0.063 liters per second (l/s) - 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

Table 17. TEST NO. 8. SUSPENDED SOLIDS MASS BALANCE

| Time | Influent flow rate l/s [a] | Accumulative mass in kilograms [b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & overflow kg |
| 0800 | 233.4 | 125.1 | 11.3 | 47.8 | 59.2 |
| 0900 | 242.9 | 280.7 | 25.1 | 83.3 | 108.3 |
| 1000 | 242.9 | 438.0 | 36.8 | 126.8 | 163.6 |
| 1100 | 239.7 | 560.5 | 48.2 | 180.6 | 228.8 |
| 1200 | 236.6 | 669.4 | 67.0 | 232.8 | 299.8 |
| 1300 | 230.3 | 752.3 | 80.1 | 284.0 | 364.1 |
| 1400 | 227.1 | 840.6 | 91.2 | 335.0 | 426.3 |
| 1500 | 217.6 | 936.1 | 104.6 | 384.2 | 488.8 |
| 1600 | 208.2 | 1039.4 | 120.7 | 425.9 | 546.6 |
| 1700 | 195.6 | 1097.1 | 134.6 | 467.9 | 602.5 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

Table 18. TEST NO. 9. SUSPENDED SOLIDS MASS BALANCE

| Time | Influent flow rate l/s[a] | Accumulative mass in kilograms[b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & overflow kg |
| 0800 | | | | | |
| 0900 | | | | | |
| 1000 | 183.0 | 55.9 | 8.7 | 20.9 | 29.6 |
| 1100 | 195.6 | 177.7 | 18.2 | 41.9 | 60.1 |
| 1200 | 220.8 | 268.3 | 33.4 | 93.9 | 127.3 |
| 1300 | 239.7 | 354.5 | 48.4 | 134.6 | 183.0 |
| 1400 | 233.4 | 441.1 | 61.2 | 179.6 | 240.8 |
| 1500 | 227.1 | 504.8 | 71.6 | 227.3 | 298.9 |
| 1600 | 227.1 | 567.7 | 82.7 | 266.1 | 348.8 |

[a] 0.063 liters per second (l/s) - 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb)

Table 19. TEST NO. 9. BOD MASS BALANCE

| Time | Influent flow rate l/s [a] | Accumulative mass in kilograms [b] | | | |
|---|---|---|---|---|---|
| | | Influent kg | Underflow kg | Overflow kg | Underflow & overflow kg |
| 0800 | | | | | |
| 0900 | | | | | |
| 1000 | 183.0 | 112.4 | 22.5 | 188.0 | 210.4 |
| 1100 | 195.6 | | | | |
| 1200 | 220.8 | | | | |
| 1300 | 239.7 | 324.6 | 38.8 | 317.4 | 356.2 |
| 1400 | 233.4 | | | | |
| 1500 | 227.1 | | | | |
| 1600 | 227.1 | 496.2 | 65.4 | 409.4 | 474.8 |

[a] 0.063 liters per second (l/s) = 1 gallon per minute (gpm)

[b] 0.454 kilograms (kg) = 1 pound (lb.)

This brought the total BOD removed from the basin both in the underflow and in the overflow to 59% for Test No. 7 and 89% for Test No. 9. This means that approximately 41% of the influent BOD remained in the basin or was accumulated during the lower storm flow period of Test No. 7 as compared to only 11% contained in the basin during Test No. 9.

In order to compare the mass balance data for Tests 1 through 9, Tables 20 and 21 were prepared. Table 20 summarizes the total mass of Suspended Solids entering the basin in the influent and leaving the basin in both the underflow and overflow during the same seven-hour period of each test. Table 21 summarizes the total mass of BOD entering and leaving the basin during the same seven-hour period. To aid in the evaluation of the mass balance data in Tables 20 and 21, the following information is pertinent to the individual test conditions.

Test Nos. 1 and 2 were parallel tests with the only difference being in the amount of time prior to the actual test that solids were allowed to accumulate in the basin.

Test Nos. 2 and 3 were run consecutively with the Pool Sweeps removed from the service during Test No. 3.

Test Nos. 2 and 4 were parallel tests with the influent flow diverted away from the Sedimentation-Equalization Basin during Test No. 4.

Test Nos. 4 and 6 were parallel tests except that Test No. 6 was run during the winter when the normal flow rate was higher and the resulting waste strengths were less.

Test No. 5 was normal winter operation with minor storm flows of 75.7 to 126 l/s (1,200 to 2,000 gpm).

Test No. 7 was normal winter operation with moderate storm flows of 145 to 170 l/s (2,300 to 2,700 gpm).

Test No. 8 was normal winter operation with heavy storm flows of 196 to 243 l/s (3,100 to 3,850 gpm).

Test No. 9 was normal winter operation with heavy storm flows of 183 to 240 l/s (2,900 to 3,800 gpm).

Table 20. SUMMARY OF SUSPENDED SOLIDS MASS BALANCES

| Test No. | Mass in 7 hours[a], kg[b] | | | Percent of influent | | |
|---|---|---|---|---|---|---|
| | Influent | Underflow | Overflow | Underflow | Overflow | Remained In Basin |
| 1 | 356 | 283 | 50 | 80% | 14% | 6% |
| 2 | 262 | 79 | 42 | 30% | 16% | 54% |
| 3 | 277 | 48 | 37 | 17% | 13% | 70% |
| 4 | | 67 | | | | |
| 5 | 230 | 65 | 99 | 28% | 43% | 29% |
| 6 | | 42 | | | | |
| 7 | 342 | 70 | 127 | 20% | 37% | 43% |
| 8 | 759 | 96 | 343 | 13% | 45% | 42% |
| 9 | 568 | 83 | 266 | 15% | 47% | 38% |

[a]To enable a comparison of all tests, the mass data is for the seven-hour period from 10:00 to 17:00.

[b]0.454 kilograms (kg) = 1 pound (lb)

Table 21. SUMMARY OF BOD MASS BALANCES

| Test No. | Mass in 7 hours[a], kg[b] | | | Percent of influent | | |
|---|---|---|---|---|---|---|
| | Influent | Underflow | Overflow | Underflow | Overflow | Remained In Basin |
| 1 | | 266 | 109 | 88% | 36% | -24% |
| 2 | | 211 | 145 | 47% | 32% | 21% |
| 3 | 408 | 125 | 128 | 31% | 31% | 38% |
| 4 | | 247 | | | | |
| 5 | 613 | 206 | 100 | 34% | 16% | 50% |
| 6 | | 86 | | | | |
| 7 | 643 | 96 | 283 | 15% | 44% | 41% |
| 8 | | | | | | |
| 9 | 440 | 54 | 315 | 13% | 72% | 15% |

[a]To enable a comparison of all tests, the mass data is for the seven-hour period from 10:00 to 17:00.

[b]0.454 kilograms (kg) = 1 pound (lb)

# SECTION VI

# DISCUSSION

## GENERAL

As used in this report, the term surge facility represents the total facility, including raw sewage pumps, Sedimentation-Equalization Basin, underflow pumping, storage pond and overflow chlorination, whereas the term Sedimentation-Equalization Basin refers only to the basin itself along with the associated influent pipe, Pool Sweeps, aerator, overflow structure and skimming structure.

In the development of a surge facility, there are two main items of concern. The first is the control of the hydraulics of the system; that is, the control of the volume and rates of flow of the wastewater through the facility. The second is the control of the solid portion of the wastewater.

The control of the hydraulics is only dependent on the inflow and outflow rates including average, minimum, maximum and duration. The sizing of all storage, pumping and control facilities can be based on these parameters using sound theoretical approaches.

The control of the solids movement through surge facilities is not nearly so cut and dried. Since a surge facility practically by definition is a settling basin, there will be some separation of solids in its normal operation. The size, shape and flow pattern of a surge facility will govern the amounts of solids separation that will take place. The deposition of solids can be desirable in cases where partial treatment is desired or if the operation of the basin is set up to remove accumulated solids periodically and perhaps truck the concentrated sludge to the treatment plant directly. In most cases, however, the surge facility is used only to store excess wastewaters until they can be placed back into the waste stream or treatment process. In these cases, the objective or goal is to be able to return all of the solids. Any solids remaining in a surge facility become a handling problem at the least; and in the case of domestic waste solids, can also become a nuisance or even a health hazard.

At the present time, the three generally accepted methods of preventing the accumulation of sewage solids in a surge or storage facility is with mechanical collection equipment installed in a specially designed concrete structure, by providing very steep side slopes to a central draw-off point, or by providing mixing with sufficient power to keep the wastewater contents completely mixed. In the first case, the mechanical sludge collection equipment and necessary structure(s) are expensive. In the second case, the restriction on structural

shape, primarily the depth of sumps, eliminates this alternative except for perhaps the very smallest facilities. In the third case, the power cost to provide sufficient mixing is also expensive; and with the contents of a surge facility completely mixed, any overflow would contain an excessive amount of solids which would then accumulate in a storage facility if one exists or be discharged as effluent.

## HYDRAULIC CONTROL

The ability to control the Sedimentation-Equalization Basin to produce the desired uniform flow rate was documented early in the Demonstration Period. With the influent and underflow metered and the water surface monitored continuously, it was relatively easy to produce a uniform underflow rate during normal dry weather flow periods while maintaining a desired variation in water surface and preventing overflow to the storage pond. The Sedimentation-Equalization Basin volume of approximately 3/4 of the average daily flow appears to be adequate for this purpose. The design of the Sedimentation-Equalization Basin provides for a volume of approximately 378.8 $m^3$ (100,000 gallons) in the top 0.3 m (1.0 ft) when the water surface is at elevation 99.0.

## OVERFLOW QUALITY

One of the principal objectives of the Sedimentation-Equalization Basin is to minimize the strength of the waste which overflows into the storage pond. To minimize potential operation problems, such as nuisance from odors or flies or ultimate removal requirements, associated with the deposition of solids and the intermittent filling and drying of an overflow storage pond, it is important that all wastes discharged to the pond be as low in solids, and particularly Settleable Solids, as possible. To show the quality improvement which was gained through the basin during the testing periods, Table 22 was prepared. This table indicates the percent removal of BOD, Suspended Solids and Settleable Solids through the Sedimentation-Equalization Basin during the portion of each major test in which there was a significant overflow to the storage pond. Tests C, $D_1$, and $D_2$ were not included because test procedures and low storm flows resulted in almost no overflow. Comparing the various tests, it can be seen that the influent flow rate varied from 56.8 to 227.1 l/s (900 to 3,600 gpm), and the resulting theoretical hydraulic detention time varied from 13.9 to 3.6 hours. The first thing which can be seen is that the operation of the Sedimentation-Equalization Basin and its configuration and flow characteristics cause it to operate less efficiently than a conventional clarifier. At the relatively long hydraulic detention times, 3.6 to 13.9 hours, the removal efficiency for Settleable Solids, Suspended Solids and BOD were all significantly lower than you could expect from a conventional clarifier. The principal reasons for this are the short-circuiting which is likely to occur due to the relative position

of the influent and overflow in the basin and the effects of the accumulation of solids in the basin. The short-circuiting is thought to be the major cause of the lower Settleable and Suspended Solids removals while the accumulation of solids in the basin is almost certainly the cause of the erratic and generally low values of BOD removal.

The BOD removals are most unpredictable and seem not directly dependent on hydraulic loadings. There is a trend in the removals of Suspended Solids which indicates that when the hydraulic loading approached a 3-hour detention time, the removals were reduced to approximately 45% from approximately 55% at the longer detention times. The Settleable Solics removals remained high in all the tests and did not show signs of decreased quality until the theoretical detention time dropped below five hours.

Table 22. AVERAGE OVERFLOW QUALITY

| Test No. | Influent Rate l/s[b] | Detention Time Hours | Overflow Rate l/s | Percent Removal[a] | | |
|---|---|---|---|---|---|---|
| | | | | Settleable Solids | Suspended Solids | BOD |
| 1 | 56.8 | 13.9 | 22.1 | 99 | 54 | -12 |
| 2 | 58.0 | 13.6 | 23.3 | 98 | 53 | 26 |
| 3 | 63.7 | 12.4 | 29.0 | 97 | 68 | 31 |
| 5 | 89.6 | 8.8 | 51.7 | 99 | 34 | 79 |
| 7 | 151.4 | 5.2 | 111.7 | 98 | 44 | 31 |
| 8 | 227.1 | 3.5 | 189.3 | 94 | 48 | |
| 9 | 218.3 | 3.6 | 180.4 | 90 | 44 | 0 |

[a]Percent of influent removed in basin prior to overflow to storage pond. Based on average concentration in mg/l over the test period.

[b]0.063 liters per second (l/s) = 1 gallon per minute (gpm)

## SOLIDS MOVEMENT

One of the primary functions of the Sedimentation-Equalization Basin is to maintain the flow of solids through the surge facility while damping out the hydraulic peaks. The following section discusses the pertinent factors affecting the flow of solids through the Demonstration Project facilities. The discussion

is based on the evaluation of test results described in Section V and on the practical experience gained through operation of the surge facility.

Parameters Affecting Solids Movement

Those components of the design which were expected or found to have an effect on the solids movement through the surge facility included: 1) basin configuration; 2) underflow pumping; 3) aerator; 4) Pool Sweeps; and 5) the hydraulic loading.

Basin Configuration -

The following elements of the basin configuration were found to have an effect on the movement of solids through the Sedimentation-Equalization Basin: 1) side slopes; 2) bottom slope; 3) influent configuration; and 4) depth of water in the basin.

Although the slope of the sides of the basin were designed as steep as the soil conditions would allow (two horizontal to one vertical) it was not steep enough to prevent the deposition of solids. The bottom slope was purposely designed flatter to simulate the probable conditions which would exist if this facility were larger and the bottom slope could not be made steeper. The flatter slopes were also the testing grounds for the Pool Sweep units. There is no doubt that under the conditions tested, the solids movement through the basin is directly affected by the slope of the sides and bottom.

The configuration of the influent pipe in relation to the center sump and underflow draw-off point has an effect on the movement of solids through the basin. When designed, the decision was made to introduce the waste into the basin in a vertical direction in order to direct the influent upward into the aerator. During the dry weather periods, this allowed the incoming raw waste, which generally had no DO, to be aerated and mixed with the contents of the basin. Without the aerator, the flow still wells up to the surface due to initial velocity and convective currents produced by the difference in wastewater temperatures, i.e., influent normally warmer.

If the influent pipe had been turned down, it is felt that two different conditions would have existed depending on the relative rate of influent versus underflow. If the influent was less than the underflow, it is likely that all influent would go directly to the underflow with the difference being made up of basin contents from adjacent to the center sump. Suspended Solids near the center sump would probably be drawn into the underflow. If the influent was greater than the underflow, however, the excess would be deflected back out of the center sump creating a vertical velocity past the edge of the center sump which could hinder or even stop the movement of Suspended Solids into the underflow. Test Nos. 4 and 6, which were both run without an influent flow, were designed to test

the effects of the basin influent configuration on the movements of solids. The tests and their results were discussed in Section V. The two tests did not provide sufficient data to make a positive determination of the effects of the influent configuration on the movement of solids through the basin. It did appear, however, that with the aerator off and at the flow rates tested, the influent configuration had only a small effect on the overall movement of Suspended Solids through the basin. For example, the absence of the influent flow did cause the Settleable Solids concentration in the underflow to decrease slightly. It is believed that this was caused by the absence of the heavier influent solids which were going directly into the bottom sump and out with the underflow.

The depth of water, or more appropriately, the ratio of depth to surface area, also has an effect on solids movement through the basin. A shallow basin has the effect of damping out any flow patterns in the outer areas of the basin, thus creating more "dead" areas. The flow patterns mentioned would be those caused by convective or velocity currents from the influent pipe or by the aerator.

Underflow Pumping -

The underflow pumping rate appears to affect the movement of solids based on two criteria. First the ratio of underflow to influent flow and second the ratio of underflow to basin volume. As the ratio of underflow to influent flow increases, there is a tendency for more of the Suspended Solids to be removed before they have time to settle. The ratio must be quite high, approaching one, before a significant increase in the amount of Settleable Solids is noticed in the underflow, however. As the ratio of underflow to basin volume increases, there is the same tendency to capture more Suspended Solids before they settle; but in addition, the higher underflow rate causes the bottom currents moving radially inward to increase and, thus, cause settled bottom deposits to be moved inward. Based on observed operations and on test results, it appears that the inward radial currents are only able to move solids if they are quite close to the rim of the center sump and if they have already been dislodged from the bottom. Therefore, it is concluded that the influence of the bottom currents toward the movement of deposited solids is slight.

Aerator -

The Sedimentation-Equalization Basin has two modes of operation depending on the aerator being on or off. The following discussion is relative to the conditions which exist when the aerator is on, normally when flows are lower.

The surface type floating aerator has two principal functions, i.e., to supply oxygen to the wastewater in the basin and to provide mixing of the basin contents. The amount of mixing that takes place is a function of the size

(horsepower) of the aerator. If sufficient power were provided, the basin could be completely mixed and solids deposition would be all but eliminated. This, however, could require as much as five times the size and horsepower of the existing unit. As designed for this project, the aerator was sized to provide oxygen to maintain DO in the basin but not to provide complete mixing. The action of the aerator is to draw the wastewater up from beneath the unit and then discharge it radially outward from the center at the water surface. In the process, the wastewater is aerated in an artificial hydraulic jump created by the revolving rotor. The currents generated by the aerator are radially outward on the surface and then roll under and are radially inward on or near the bottom. In the Sedimentation-Equalization Basin, the visual observation of flow and current patterns indicates that velocities in the outer edges of the basin are very small. The resulting effects of the aerator on the movements of solids in the outer areas of the basin are probably small. Near the center of the basin the solids tend to be resuspended by the inward and upward currents, letting only the heaviest solids settle downward into the center sump.

Pool Sweeps -

The function of the Pool Sweeps, which were described in Section IV, was to continuously "sweep" the bottom and sides of the basin to move and temporarily resuspend the settled sewage solids. Those operational parameters of the Pool Sweeps which are felt to affect their performance when used for this application include: 1) the mobility of the main body or floating portion of the unit; 2) the quantity and pressure of the supply water; 3) the quality of the supply water; 4) the length and number of sweep hoses; and 5) the jet nozzle sizes at the ends of the sweep hoses.

In a swimming pool, the Pool Sweep maintains its motion in two ways. First is the thruster jets and second is the circular rotating ring which forms the base of the unit (see Figure 6). In the Sedimentation-Equalization Basin, the Pool Sweeps were "tethered" on the supply hoses from the distribution points around the edge of the basin. This restraint did not allow the units to hit and run along all four sides as they do in a swimming pool. Instead, they move outward toward the center of the basin and when they reach the end of the line they slow down and finally stop as the pull of the supply hose matches the force of the main thruster. The lack of "random" motion significantly reduced the frequency of coverage for any particular area on the basin floor.

The action of the thruster jets is regulated by an internal valve in the main body which directs the water to the rear main thruster or to the front reversing thruster. The cut of the valve was modified during the initial phases of the Demonstration Project to improve its mobility. It was found that the modifications could not significantly increase the mobility of the units.

The water supply for the Pool Sweeps is from the primary clarifier effluent and is pumped to the common supply line encircling the Sedimentation-Equalization Basin. The amount of water and the pressure affect both the mobility of the main body of the Pool Sweeps and the mobility of the underwater "sweep" hoses. The normal operating pressure for the Pool Sweeps when used in a swimming pool is about 2.81 to 3.52 kgf/cm$^2$ (40 to 50 psig). The operating pressure for the Demonstration Project system was increased from 4.22 to 4.92 kgf/cm$^2$ (60 to 70 psig). This was the maximum pressure recommended by the Pool Sweep manufacturer. The increased pressure did increase the action and power of the sweep hoses but no significant increases in the solids movement through the basin could be determined. In conjunction with the increased pressure, the hose jet size was varied to determine the optimum combination of pressure and volume from the sweep hoses which would produce the most forceful action of the hoses. The major portion of these tests were performed by the Pool Sweep manufacturer in a swimming pool prior to placing them in the Sedimentation-Equalization Basin. In this way, the bottom hoses could be observed as each change was made. When placed in the wastewater of the Sedimentation-Equalization Basin, the only observable feature of the Pool Sweep was the floating body and its movement.

The length and number of Pool Sweep hoses was anticipated to affect the movement of solids through the basin. The normal design of the Pool Sweep system includes two hoses, one called the bottom hose and the other called the wall hose. The bottom hose is long enough so that when the Pool Sweep is in the deepest part of the basin the bottom two feet of the hose rests on the floor. The wall hose is generally several feet shorter and is not intended to sweep the bottom. The initial Demonstration Project installation included both hoses as just described.

Following the first set of tests, including the first 24-hour Test No. 1, the Pool Sweep representatives developed a "wye" assembly which allowed a single longer bottom hose to be operated with the combined water of the original two hoses. This change in configuration showed improved force and mobility in swimming pool tests conducted by the manufacturer. The "wye" assembly was previously shown in Figure 8. The "wye" assemblies were installed on all of the Demonstration Project Pool Sweeps, however, subsequent tests were not able to show a significant improvement which could be attributed to the hose modification.

Hydraulic Loading -

High hydraulic loadings through the Sedimentation-Equalization Basin result in an increase in the percentage of influent solids which are carried out in the overflow and a decrease in the percentage of influent solids which are removed in the underflow. This was previously shown in Table 20. Even though the concentration of solids in the overflow remained lower than in the underflow, the high volume of overflow caused the major increase in the mass of solids in the overflow.

## OPERATION AND MAINTENANCE

In addition to the normal operation and maintenance (O&M) of the standard waste treatment equipment, the Demonstration Project had additional O&M associated with the surge facility and related equipment; namely, Pool Sweeps.

The operation and maintenance of the Sedimentation-Equalization Basin, in general, consisted of hosing down the sides and periodically removing the accumulated floating grease. Grease removal could be accomplished by hand loading into a dumpster to be hauled away or by controlling the surface drawoff at the skimming structure. Its position in the basin allowed the prevailing winds to collect the grease in front of the skimming structure and, consequently, no mechanical skimming was required.

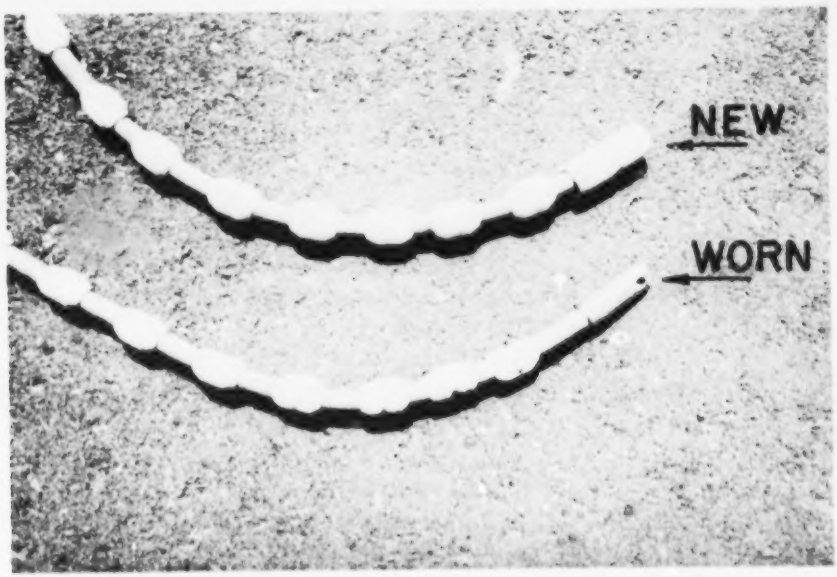
The use of the Pool Sweeps was accompanied by several special O&M problems which were related to either the water supply or to the configuration of the Sedimentation-Equalization Basin.

The water supply selected for operating the Pool Sweeps was primary clarifier effluent. This was chosen rather than tap water, which was available, because the anticipated future use of these units quite possibly would be where an adequate supply of pure water would not exist or was uneconomical to use. The poorer quality water caused two major problems. First, the internal valving of the Pool Sweep has close tolerances and small pieces of plastic or similar material would completely immobilize the units when they would become lodged inside the main body of the Pool Sweep. The clarifier at the Rohnert Park facility was heavily loaded and it is possible that a more efficient clarifier would help this problem. The second O&M problem caused by the quality of the water supply was the accumulation of grease in the interior of the main Pool Sweep body which would eventually alter the operation of the unit or plug it completely. This phenomenon can be expected with all primary effluents which contain a normal amount of grease and oils.

The configuration of the basin caused problems with the operation of the Pool Sweeps. First, the finish on the gunite lining (float finish) proved to be far too abrasive for the wearing materials on the sweep hoses. Under continuous use, the hoses would wear so severely that the ends of the hoses would wear completely out in as short a time as two months. A picture of a new and worn hose end is shown in Figure 24. The second problem associated with the basin configuration was the presence of the overflow structure out in the basin. The Pool Sweep covering that area of the basin would periodically get in behind the structure and could not get out by itself. Another problem which could be avoided in most cases was the tangling of the Pool Sweep units. The Pool Sweeps would not

tangle as long as the supply hoses were short enough not to allow the main bodies to overlap the same area. When just the bottom hoses overlapped, tangling did not occur.

Figure 24. Pool Sweep Hose Wear




If solids were allowed to accumulate on the bottom of the basin as a routine method of operation, most could be removed by simply drawing down the basin with the underflow pumps. The operational problems associated with the long detention time of the bottom sludge, primarily the production of nuisance odors, would exist and would detract from the feasibility of using this as a normal mode of operation. The approximate cost of removing the concentrated sludge would be in the range of $25.00 to $30.00 per 1,000 gallons and would be additive to the normal costs of a surge facility since the other components are designed based on hydraulic capacity which would not change.

## MODIFICATIONS TO SURGE FACILITY

Based on the information gained through the evaluation of test results and the actual operation of the surge facility, there appears to be several areas where a desig or operational change could benefit its operating characteristics.

To prevent the problems caused by the poor quality of the water supply to the Pool Sweeps, it is felt that a clarified secondary effluent or better is required. If the required basin size is not much greater than the Rohnert Park facility, the slope of the sides and bottom could be increased to improve the flow of solids toward the center sump.

The structure for skimming and overflow should be set back into the levees so that there is no obstructions within the basin which could hinder the operation of Pool Sweeps or other sludge-moving equipment.

The lining of the basin should be as smooth as possible to prevent excessive wear. If gunite is used, it should have a steep trowel finish and a durable coating of cement sealer, e.g., epoxy. The use of a flexible lining such as a hypalon or molded asphalt panels could be an acceptable material if the movement of the bottom Pool Sweep hoses would not wear the lining. This would have to be investigated.

One of the principal shortcomings of the Pool Sweep mode of operation as used in this Demonstration Project was that the sweeping action is random. Without a stronger inward bottom current or steeper bottom slopes, it does not appear that there could ever be a significant net movement of solids toward the center sump. At this time, it does not appear that the Pool Sweeps can be modified to provide a uni-directional sweeping action toward the center sump.

An alternative means of moving the settled sludge along the bottom and, in particular, toward the center sump, would include fixed underwater sprays or jets directed toward the center sump. The spacing of the spray nozzles or ports would be quite critical and would probably require considerable testing to establish an efficient design.

Another alternative way would be a series of high pressure nozzles mounted on a manifold pipe which would be fed through a pivot point in the center of the basin. The manifold would extend radially outward from the center and would have intermediate roller supports along its length. The drive for the manifold, which would rotate around the basin approximately every hour, could be one or more water-driven motors operating on the same water supply system as the manifold itself. Special attention would have to be given to the positioning and operation of the aerator since no supports or guide posts could be placed in the path of the rotating manifold and the pond could not be lowered without first stopping the manifold in the proper location to miss the aerator float supports.

During the dry weather flow periods when there is generally no overflow, there are other alternatives for maintaining the flow of solids. The most obvious is to provide enough horsepower for the aerator to keep all of the solids in suspension.

The operating costs of the larger aerator would be approximately five times as much as the present one; and in addition, the physical dimension of the basin would probably have to be altered somewhat to increase the depth to surface area ratio. The present Rohnert Park facility has a water depth of 8 to 10 feet, and the average distance across is about 130 feet. This fairly shallow basin would be quite inefficient if an attempt were made to keep it completely mixed. A completely mixed basin would have an additional benefit of providing the possibility of some treatment as well as flow control. The present facility was not able to provide any significant treatment through aeration and recycle of solids from the clarifier because the flow of solids could not be maintained through the basin.

Another possibility is to use a variable speed aerator and/or a variable pitch turbine mixer to minimize the operating costs for a basin which need not be mixed all of the time but does need to be completely mixed to suspend the settled sludge for removal from the basin.

If solids are allowed to accumulate in the basin and then be removed periodically as previously discussed, only minor modification to the existing facilities would be required. Principally, the discharge pipe from the underflow pumps to the clarifier would have to be modified to allow concentrated sludge to be pumped directly into trucks to be hauled to the regional treatment facility.

## ECONOMIC EVALUATION

In order to illustrate the economics of surge facilities, a set of hypothetical alternatives was assumed for the Laguna de Santa Rosa planning sub-area of which Rohnert Park is a part. The long-range planning for this area calls for the existing treatment facilities at Rohnert Park, Sebastopol and Santa Rosa's College Avenue site to be abandoned and replaced with pumping and transmission facilities to transport all wastes to the Laguna Regional Wastewater Treatment Facility. In addition, there is an area of the county which is presently sewered to the Regional Plant. All of the present sewerage systems have high ratios of peak wet weather to average dry weather flows and the possibility of excess infiltration/inflow. The cost-effective evaluation of infiltration/inflow problems for all four areas should include the use of surge facilities. For the purpose of comparison, the following assumptions were made: 1) each of the four tributary areas would be served by a separate pump station or surge facility; 2) the regional treatment plant will be an activated sludge secondary facility using digesters for sludge treatment; and 3) the interceptors will be gravity sewers averaging ten to twelve feet deep.

Each surge facility will have influent and underflow pumping, a surge basin with three hours' detention at peak flow, a storage basin approximately six feet deep with two days' detention at maximum daily flow, a control building and a chlorination facility for emergency wet weather overflow.

The formal design criteria for treatment facilities takes into account daily peaks which for this regional facility would be approximately 1.7 times average daily flow. This means, for example, that a primary clarifier designed to handle 1.0 mgd at an overflow rate of 800 gpdsf would be expected to operate efficiently during the daily peaks which would be approximately 1.7 mgd or an overflow rate of 1,360 gpdsf. Applied to the idea of a constant flow 24-hour per day, this means that a plant could logically be designed at these higher rates and that approximately sixty percent of the plant size would be required for all those units where the hydraulics control. The solids handling facilities would not be affected, however. Those elements of a secondary activated sludge treatment plant which could be reduced in size by having a constant influent flow include: 1) headworks; 2) metering; 3) all sewage pumping; 4) primary sedimentation tanks; 5) aeration basins; 6) secondary sedimentation tanks; and 7) disinfection facilities.

Flow data for all areas were taken from the March 1973 report, "Subregional Wastewater Management Plan for the Santa Rosa Plain," by Brown and Caldwell, Water Resources Engineers, Inc. and Yoder-Trotter-Orlob & Associates.

The cost estimating data came from a set of unpublished preliminary cost estimating curves and tables used by Yoder-Trotter-Orlob & Associates for work in the San Francisco Bay Area. Although the cost estimates presented are as accurate as possible they should not be used by others for similar work. Their value lies in having a timely basis for a relative cost comparison.

Based on the construction and operation of the Rohnert Park Demonstration Project, it is estimated that the construction cost of a surge facility will vary depending on the size of the facility as follows: the larger facility will cost approximately 1.33 times the cost of a typical raw sewage pump station which will handle the same peak wet weather flow; the smallest will cost approximately 2.0 times. It is also estimated that the operation and maintenance cost for a surge facility will average approximately 1.5 times that for a similar sized pump station.

A schematic diagram indicating the regionalization scheme is shown in Figure 25. This figure indicates the projected average dry weather flows (adwf) and peak wet weather flows (pwwf) for 1985 for each separate area. Also indicated is the maximum or peak flow rate which would result if a surge facility were used instead of a standard pumping station at each location. The respective interceptor sizes, depending on whether or not a surge facility is used, are also indicated. Tables 23 and 24 summarize the estimated cost which would be associated with the two alternatives. Both the estimated capital cost and estimated annual operation and maintenance (O&M) costs are presented. The estimated O&M costs on the interceptors did not differ significantly between alternatives and was, therefore, left out of the economic comparison.

Figure 25. Regional Wastewater System Schematic

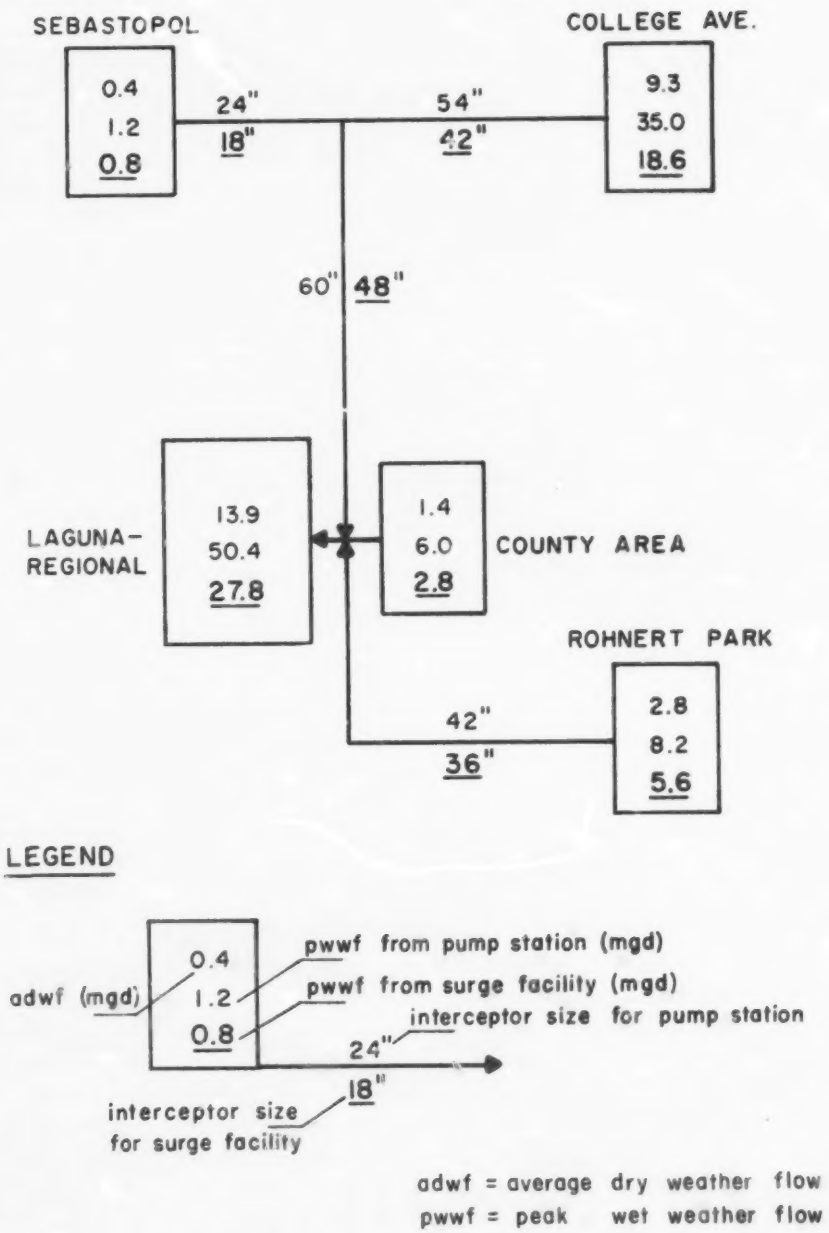


Table 23. COST SUMMARY - ALTERNATE 1
REGIONALIZATION WITHOUT SURGE FACILITIES

| Item | Annual O&M | Capital cost |
|---|---|---|
| Regional Treatment Plant | | |
| Design adwf, 13.9 mgd | $490,000 | $ 9,400,000 |
| Design pwwf, 50.4 mgd | | |
| Local Pumping Stations | | |
| College Avenue, 35.0 mgd | $ 25,500 | $ 1,000,000 |
| County Area, 6.0 mgd | 5,850 | 310,000 |
| Rohnert Park, 8.2 mgd | 10,000 | 380,000 |
| Sebastopol, 1.2 mgd | 2,250 | 108,000 |
| Subtotal | $ 43,600 | $ 1,798,000 |
| Interceptors to Regional Plan | | |
| College Avenue - | | |
| 18,000 ft - 54 in. @ $82.20/ft | | $ 1,480,000 |
| Sebastopol - | | |
| 10,000 ft - 24 in. @ $31.90/ft | | 319,000 |
| College Avenue and Sebastopol (combined) - | | |
| 18,000 ft - 60 in. @ $90.40/ft | | 1,627,000 |
| County Area - | | |
| (No interceptor required) | | - |
| Rohnert Park - | | |
| 22,000 ft - 42 in. @ $60.85/ft | | 1,340,000 |
| Subtotal | | $ 4,766,000 |
| Total Annual O&M Cost | $533,600 | |
| Total Capital Cost | | $15,964,000 |

Table 24. COST SUMMARY - ALTERNATE II
REGIONALIZATION WITH SURGE FACILITIES

| Item | Annual O&M | Capital cost |
|---|---|---|
| Regional Treatment Plant | | |
| Design adwf, 8.4 mgd | $385,000 | $ 7,370,000 |
| Design pwwf, 27.8 mgd | | |
| Local Surge Facilities | | |
| College Avenue, 35.0 mgd | $ 38,200 | $ 1,333,000 |
| County Area, 6.0 mgd | 8,800 | 558,000 |
| Rohnert Park, 8.2 mgd | 15,000 | 647,000 |
| Sebastopol, 1.2 mgd | 3,400 | 216,000 |
| Subtotal | $ 65,400 | $ 2,754,000 |
| Interceptors to Regional Plant | | |
| College Avenue - | | |
| 18,000 ft - 42 in. @ $60.85/ft | | $ 1,095,000 |
| Sebastopol - | | |
| 10,000 ft - 18 in. @ $24.65/ft | | 246,500 |
| College Avenue and Sebastopol (combined) - | | |
| 18,000 ft - 48 in. @ $73.15/ft | | 1,318,000 |
| County Area - | | |
| (No interceptor required) | | - |
| Rohnert Park - | | |
| 22,000 ft - 36 in. @ $48.65/ft | | 1,071,000 |
| Subtotal | | $ 3,730,500 |
| Total Annual O&M Cost | $450,400 | |
| Total Capital Cost | | $13,854,500 |

There are several benefits which would be gained if surge facilities were used which are extremely valuable but do not show up in an economic analysis. All these benefits are related primarily to the uniform flow delivered to the regional plant and can be grouped into three main categories: performance, reliability, and flexibility.

The performance of secondary treatment facilities, and in particular, a biological system, is strongly affected by either hydraulic or concentration surges. Most upsets which result in decreased effluent quality are caused by these surges or slugs. The surge facility mode of operation allows the hydraulic surges to be eliminated and the waste concentration (strength) variations to be dampened to whatever level required by varying the design of the surge facility. The uniform flow and strength allows each unit process to operate in a stable mode of operation and at peak efficiency.

The reliability of the regional treatment plant is enhanced by the use of a surge facility in the same way as performance is affected. For a treatment plant to be reliable it should operate efficiently and not be easily upset. The use of a surge facility removes hydraulic surges and dilutes slugs of high strength or even toxic wastes, thereby minimizing the principal causes of upset processes.

The use of a central regional plant and several remote surge facilities has a large degree of flexibility which would not exist if simple pump stations were used. The large storage facilities which are used primarily for winter overflow could be easily used as treatment units (ponds) during the dry weather flow. If lightly loaded, the ponds could be used to treat a portion of the waste at any of the remote locations for local reuse.

## SECTION VII

## GLOSSARY

Anaerobic Digestion - The degradation of organic matter brought about through the action of micro-organisms in the absence of molecular oxygen.

BOD - Abbreviation for biochemical oxygen demand. The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. Also, a standard test used in assessing wastewater strength.

Chlorination - The application of chlorine to water or wastewater, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

Digester - A tank in which sludge is placed to permit the biological decomposition of the organic matter in the sludge and resulting in partial gasification, liquification and mineralization.

Dissolved Oxygen - The oxygen dissolved in water, wastewater, or other liquid usually expressed in milligrams per liter, parts per million, or percent of saturation. Abbreviated DO.

Domestic Wastewater - Wastewater which includes all of the water-borne wastes originating from residential, commercial, and recreational developments and the water-borne wastes originating from the sanitary facilities of industrial development.

Dry Weather Flows - Normal wastewater flow with little or no infiltration.

Effluent - Wastewater, partially or completely treated, flowing out of a treatment plant.

Infiltration - The water entering a sewer system and service connections from the ground through such means as, but not limited to, defective pipes, pipe joints, connections, or manhole walls. Infiltration does not include, and is distinguished from, inflow.

Inflow - The water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, cellar, yard, and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas manhole covers, cross connections from storm sewers and combined sewers, catch basins, stormwaters, surface runoff, street wash waters, or drainage. It does not include, and is distinguished from, infiltration.

Infiltration/Inflow - The total quantity of water from both infiltration and inflow without distinguishing the source.

Influent - Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment plant, or any unit thereof.

Organic matter - Chemical substances of animal or vegetable origin, or more correctly, of basically carbon structure, comprising compounds consisting of hydrocarbons and their derivatives.

Outfall - A conduit leading from a treatment plant or wastewater collection system to the point of final discharge.

pH - The reciprocal of the logarithm of the hydrogen-ion concentration. The concentration is the weight of hydrogen-ions, in moles, per liter of solution. Neutral water, for example, has a pH value of 7 and a hydrogen-ion concentration of $10^{-7}$ moles per liter.

Present Worth - The present worth of a cost occurring at some future point in time is the present amount of money, that when invested at a selected interest rate, will be at that particular future time worth that amount.

Primary Treatment - The first major (sometimes the only) treatment in a wastewater treatment plant, usually sedimentation. Primary treatment removes a substantial amount of suspended matter but little or no colloidal and dissolved matter.

Secondary Treatment - The treatment of wastewater by biological methods after primary treatment by sedimentation.

Sedimentation - The process of subsidence and deposition of suspended matter carried by water or wastewater, by gravity. It is usually accomplished by reducing the velocity or wastewater below the point at which it can transport the suspended matters.

Sewage - The spent water of a community. Term now being replaced in technical usage by the more preferable term, wastewater. See Wastewater.

Sludge - The accumulated solids separated from liquids such as water or wastewater, during processing, or the deposits on bottoms of streams or other bodies of water. Also, the precipitate resulting from chemical treatment, coagulation or sedimentation of water or wastewater.

Sludge Digestion - The process by which organic or volatile matter in sludge is gasified, liquified, mineralized, or converted into more stable organic matter through the activities of either anaerobic or aerobic organisms.

Suspended Solids - Solids that either float on the surface or are in suspension in water, wastewater, or other liquids, and which are largely removable by laboratory filtering.

Tertiary Treatment - The treatment of wastewater beyond secondary treatment by using various physical and chemical processes. Tertiary treatment can include processes to remove additional suspended solids, BOD or algal nutrients like nitrogen or phosphorus.

Turbidity - A condition in water or wastewater caused by the presence of suspended matter which results in the scattering and adsorption of light rays. Also, a measure of fine suspended matter in liquids.

Wastewater - The spent water of a community. From the standpoint of source, it may be a combination of the liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions, together with any groundwater, surface water, and stormwater that may be present. In recent years, the word "wastewater" has taken precedence over the word "sewage."

Wastewater Reclamation - Treatment of wastewater for reuse, either for irrigation of agricultural lands or landscape, for groundwater recharge, for stream flow augmentation, for surface impoundments, or for industrial purposes.

Wastewater Treatment - Any process to which wastewater is subjected in order to remove or alter its objectionable constituents and thus render it less offensive or dangerous. See Primary Treatment, Secondary Treatment, Tertiary Treatment.

Wastewater Treatment Plant - An arrangement of devices and structures for treating wastewater, industrial wastes, and sludge. Sometimes used as synonymous with waste treatment plant, water pollution control, or water reclamation plant.

Wet Weather Flow - A combination of dry weather flows and infiltration/inflow which occurs as a result of rainstorms. This flow, in older or poorly constructed systems, can be many times the dry weather flow.

## SECTION VIII

## ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| adwf | Average dry weather flow |
| BOD | Biochemical oxygen demand |
| cu.ft. | Cubic feet |
| cu.m. | Cubic meter |
| ft. | Feet (foot) |
| gal. | gallon |
| gad | gallons per acre per day |
| gpd | gallons per day |
| gpdsf | gallons per day per square foot |
| gpcd | gallons per capita per day |
| gpm | gallons per minute |
| hp | horsepower |
| kg | kilogram |
| l | liter |
| lbs/day | pounds per day |
| lps | liters per second |
| m | meter |
| mg | million gallons |
| mgd | million gallons per day |
| mg/l | milligrams per liter |
| pad | pounds per acre per day |
| pdwf | peak dry weather flow (hourly rate) |
| ppcd | pounds per capita per day |
| psi | pounds per square inch |
| pwwf | peak wet weather flow (hourly rate) |

| | |
|---|---|
| sq. ft. | square feet (foot) |
| sq. m. | square meter |
| Set. S | Settleable Solids |
| SS | Suspended Solids |

## SECTION IX

## METRIC UNITS AND ENGLISH EQUIVALENTS

Recommended Units

| Description | Unit | Symbol | English Equivalents |
|---|---|---|---|
| Length | meter | m | 3.28 ft. |
| | centimeter | cm | 0.3937 in. |
| Area | square meter | $m^2$ | 10.744 sq. ft. |
| | square centimeter | $cm^2$ | 0.155 sq. in |
| | Hectare ($10,000\ m^2$) | ha | 2.471 acres |
| Volume | cubic meter | $m^3$ | 35.314 cu.ft. |
| | liter | l | 0.264 gal. |
| Mass | kilogram | kg | 2.205 lb |
| Time | second | s | S |
| Velocity | | | |
| | meter per second | m/s | 3.28fps |
| Flow | cubic meter per second | $m^3/s$ | 15,850 gpm or 35.314 cfs |
| | liter per second | l/s | 15.85 gpm |
| Pressure | | | |
| | kilogram (force) per square centimeter | $kgf/cm^2$ | 14.223 psi |
| Temperature | | | |
| | degree Celsius | C | $C=\frac{5}{9}$ (F-32) |
| Hydraulic Loading | cubic meters per square meter per day | $m^3/m^2/day$ | 24.58 gpdsf |